OBSERVATION INFLATION AND SELF-ACTION INFLATION. INVESTIGATION OF SOURCE MEMORY ERRORS AS A RESULT OF ACTION OBSERVATION AND ACTION PERFORMANCE.

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Abstract

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Key words: Observation inflation, Self-action Inflation, Source Memory Errors, Mirror Neurons.

This thesis investigates two source memory errors: *observation inflation,* where observed actions are misremembered as being performed; and *self-action inflation* in which self-performed actions are misremembered as having been performed by somebody else. It has been proposed that these inflations occur because of overlapping brain activity during observation and performance. This has been attributed to mirror neurone activity. To test this, observation and self-action inflations are investigated for different types of actions (meaningful, meaningless and communicative) known to evoke different mirror neurone activity. Different age groups (young adult, and elderly) were studied as were the effects of relative ethnicity between observer and performer. The Remember-Know-Guess paradigm was used. This showed that people make inflations with high qualitative details and confidence. As anticipated, elderly participants made significantly more observation inflations than young adults. Across both age groups, significantly more inflations occurred for communicative and meaningful actions than for meaningless actions supporting the idea that mirror neurones may be involved in formation of inflations. However when the effects of relative ethnicity were included in the paradigm it was found that significantly more observation inflations were formed after observing different ethnicity actors. It has been hypothesised that if mirror neurone involvement is involved in observation inflations then the highest number of inflations are expected for the same ethnicity condition because of the overlap between participant and performer. This thesis therefore suggests a less simplistic explanation of the underlying mechanisms responsible for these types of memory error.

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List of Main Abbreviations

AD	Alzheimer’s Disease
CHI	Closed Head Injury
DRM paradigm	Deese-Roediger-McDermott paradigm
EMG	Electromyography
ERP	Event Related Potential
fMRI	Functional Magnetic Resonance Imaging
LTM	Long-term Memory
MCI	Mild Cognitive Impairment
MTL	Medial Temporal Lobe
OI	Observation Inflation
PCC	Posterior Cingulate Cortex

PET	Positron Emission Tomography
PPC	Posterior Parietal Cortex
R-K-G	Remember-Know-Guess
RT	Reaction Time
SAI	Self-action Inflation
SME	Source Monitoring Error
SMF	Source Monitoring Framework
SRRE	Self-Reference Recollective Effect
STM	Short-Term Memory
WM	Working Memory

Chapter 1

Thesis overview

1.1 Aims of the thesis

The ability to correctly recall the source of information is essential for normal memory functioning. Source monitoring error (SME) is the failure to correctly attribute the source of a memory trace (Johnson et al., 1993). For example, not being able to remember which friend told you a story, or if you actually have locked the door or only imagined it. Although occurring sporadically in the healthy population, elderly or Alzheimer's patients are more susceptible to suffer from SMEs (Ruiz-Gallego-Largo et al., 2012, Schacter et al., 1997; Haj et al., 2012).

A type of SME that has only recently been researched by a handful of studies is the Observation Inflation effect (OI) (Lindner et al., 2010, 2012; Schain et al., 2012; Lindner et al., 2014). In the OI effect, the observation of actions being performed by others results in strong and incorrect memories of actually performing those actions oneself. Lindner et al. (2010) attributes the OI effect to failures in source-monitoring, facilitated by mirror neurone activity. According to Lindner et al. (2010), the observation of actions triggers similar brain activity as when the action is actually performed i.e. mirror neurones. This leads to source confusion and results in a greater likelihood of remembering the actions as self-performed (Lindner et al., 2010; 2012; Schain et al., 2012; Lindner et al., 2014).

This thesis aims to investigate the OI effect further with regards to the possible involvement of mirror neurones. Specifically, the thesis aims to create behavioural experiments to investigate the nature of misattributions by looking at patterns of OIs for different action types: meaningful, meaningless and communicative emblems. Given that OI has only recently been studied, a strong focus of the thesis is on creating a successful experimental paradigm that allows for solid investigation of OIs. Additionally, this thesis will explore the effect of age on OI formation, social aspect of OIs, recollective experience, and the influence of instruction on the pattern of OIs.

To further test the mirror neurone hypothesis, the effect of 'Self-action Inflation' (SAI) is investigated, in which self-performed actions are incorrectly recalled as observed (performed by others).

The four introductory chapters discuss background research relevant for contextualising the OI effect, including major research in the area of memory errors, mirror neurones and action type.

The experimental chapters will consist of more detailed introduction of relevant research, followed by a description of methods applied, data analysis and results obtained; and finally the findings will be discussed in relation to the existing literature.

The discussion will summarise the main findings and evaluate them in relation to existing research on the subject and highlight the implications and areas for improvement.

1.2 Chapter overview

Chapter 2 introduces different types of memory errors and theoretical background. It begins with a brief introduction to memory systems and a history of memory error research. Following that, major false memory research is discussed. The chapter then moves on to cover cognitive theories of memory errors, including the Source Monitoring Framework. Finally, existing neuroimaging research of memory errors is explored.

Chapter 3 focuses on the discussion of memory errors and the imagination inflation effect. Imagination inflation has received scientific attention and could be considered similar to OIs. The existing literature on OI is then discussed.

Chapter 4 introduces further concepts relevant to the OI errors, including motor cognition and mirror neurone theory. Motor priming is discussed in relation to action facilitation and action imitation. Studies that demonstrate an action facilitation effect resulting from action observation are also discussed. Lastly, research on action imitation and different types of actions will be explored due to its relevance to the investigation of OIs for different types of actions.

Chapter 5 is concerned with the different states of conscious recollection of memories, considered important in memory research and used in the experimental chapters. It covers research employing the Remember-Know-Guess (R-K-G) paradigm to the study of the recollective experience.

Chapter 6 is the first experimental chapter and presents the study on OI for different types of actions (meaningful, meaningless and communicative). It was found that the highest number of OI formed was after observation of communicative and meaningful actions. The results are also presented for misattributions after different time delays and reveal highest level of OIs was formed after a two week time delay. Additionally, correct source recall of actions is discussed. Interestingly, the communicative actions resulted in the highest level of OIs and correct source attributions.

Chapter 7 is the second experimental chapter that tests the mirror neurone hypothesis in relation to source misattribution further. Here, the effect of SAI is examined. Similarly as in Chapter 6, the errors are examined with different action types and over different time delays. The highest number of SAIs was formed for meaningless and communicative actions. The correct source memory recall is also investigated.

Chapter 8 further investigates the formation of OIs errors for different action types. It discusses the formation of OI errors in the cohort of elderly participants (mean age = 72.87 years). As will be seen in Chapter 6, numbers of OIs remain low, so an elderly cohort is used here. The results show that they make a higher number of OIs compared to a young group and that testing elderly participants may makes for a better experimental paradigm for studying OIs.

Chapter 9 examines the influence of having an option to differentiate between the sources of memory during the retrieval on levels of OI and SAI misattributions. This experiment controls for biases that may occur with the methodology in the recall phase of the experiment.

Chapter 10 combines the experimental data from the OI and SAI experiments to investigate the recollective experience of OIs and SAIs (R-K-G responses). The recollections will be discussed in the context of action types. Additionally, false memory data obtained in the experiments will be analysed and compared.

Chapter 11 investigates the social aspect of OIs. The inflations are studied for different action types and actor's race. The results show observation of communicative actions leads to formation of significantly more OIs than meaningless actions. Interestingly, observation of other race individuals' results in more OIs than observation of own race actor.

Chapter 12 summarises the main findings of each experiment and discusses them in relation to relevant literature. Finally, it will discuss possible areas of improvement and suggestions for future research

Chapter 2

Memory errors – types and theories

1.1 Introduction

This chapter introduces the concept of memory errors. Knowledge and understanding of types and theories of memory errors are essential to comprehend the OI effect which itself is a specific type of memory error. This chapter will then briefly discuss the history of memory error research and false memory research, followed by the cognitive theories and physiological causes of memory errors.

2.2 Memory classifications

Memory is a cognitive ability that stores and retrieves information about past experiences (Baddeley et al., 2009). Different types of memory classifications are distinguished, usually depending on the duration of memory, characteristics and type of storage. Three main stages of memory formation are defined according to information processes: (i) encoding, (ii) storage and (iii) retrieval of information (Schacter, 1992).

Regarding the length of memory duration, the general classification based on the length of duration, includes three main types: (i) sensory memory, which is an ultra-short term memory lasting approximately half a second, (ii) short-term memory (STM), where the information is analysed and interpreted (some of the information contained in sensory memory is transferred) and finally, this information can be stored in (iii) long-term memory (LTM) (Baddeley et al., 2014).

The type of information that is being remembered constitutes another memory classification system (Baddaley et al., 2014). For example, two different memory types can be discriminated within the LTM: (i) declarative and (ii) procedural memory.

Declarative memory includes (i) semantic memories which are abstract, general knowledge facts about the world; and (ii) episodic memories of specific information related to a particular event or item (e.g. when and at what time something happened) (Baddaley et al., 2014).

2.3 Early research on memory errors

Memory processes are not free from errors and people regularly experience various memory distortions (Garry et al., 1996). Many experience such distortions on an everyday basis, for example missing a dentist appointment or being unable to recall the name of a recently met person.

A rarer type of memory distortion is a source memory error (SME), which is an inability to attribute memory to its correct source (Johnson et al., 1993). An example of a SME would be a confusion between whether someone has dreamt about something or heard a friend telling them a story about it.

One of the first experiments on memory distortions is credited to the British psychologist Frederic Bartlett (1932) who claimed that specific memories of events are stored in the brain as 'traces'. The traces would be created for all information and be associated with each other, as several traces would be formed for one particular event. When an individual encounters an event, they do not remember every detail of it, but instead based on how the event affects the individual, they form an 'attitude' about it. In other words they evaluate the event based on the beliefs or feelings they have about that particular event. These evaluations may in result influence the behaviour of individual towards a given event. Later, when one attempts to recall that event, the memory is reconstructed based on an individual’s initial attitude towards the event which may not be an accurate recollection of the event at all but the feeling of the individual's about it. Bartlett (1932) claimed that memory has either a reproductive or a reconstructive character. Reproductive memory refers to the ***accurately*** reproduced memories and reconstructive memory to the processes in which the details of a given memory are fabricated to make up for the loss of specific memories associated with that event. Bartlett (1932) compared reconstructive memory to learning to play a sport game – for example when playing tennis, one does not reproduce the exact same movements as they did when they initially learnt to play the game, but creates new movements based on the current posture they have and what is required of them in the moment of the game that they are playing there and then. Hence, every time the movement is repeated, it consists of different features, depending on the present conditions in which the movement is executed. Bartlett (1932) suggested that information with a great amount of detail and meaning is recalled using the reconstructive process whereas the information that contains less detail (e.g. words or lists) is recalled through the reproductive pathway. The general approach to research on memory distortions since then has been in accordance with Bartlett’s ideas.

2.4 False Memory and the Misinformation Effect

For many years, the research on memory distortions has focused on more 'real life' applicable stimuli to induce distortions, such as in the misinformation effect which is a change in the accuracy of memory recall caused by the information encountered after the initial encoding (Loftus et al., 1978).

The research on the misinformation effect involves complex scenarios that are more likely to occur in real life situations. Loftus (1975) found that the suggestibility of a question can change the answer given by participants in regards to recall of past personal experiences. Loftus (1975) found that participants were more likely to report having many episodes of headaches if the question asked them how often they experience headaches, than when they were asked if they experienced headaches occasionally.

The misinformation effect was also found to be present in eye witness testimony (Loftus and Palmer, 1974). In the experiment by Loftus and Palmer (1974), participants viewed a video of a car accident and were required to answer questions about the video. Among the questions asking details about the video, six critical questions were included, three of which were asking about a detail using the definite article 'the', and three using an indefinite article 'a' when asking about objects that were not presented in the videos. For example, half of the participants were asked 'Did you see **a** broken head-light?’ and the other half were asked 'Did you see **the** broken head-light?' (Loftus and Palmer, 1974). The results revealed that participants were more likely to incorrectly remember the objects that were asked about using the definite article (*the*) than with the indefinite article (*a*) (Loftus and Palmer, 1974). This shows that the mere suggestion that something 'definite' has been present before can lead to false recall of that item.

Loftus (1975) has also investigated the effect of presupposition, where previously non-presented detail is included in the question, presupposing its existence in the initial event. An example of such a question would be: ‘How fast was the car going when it ran the stop sign?’ (Loftus, 1975). The question suggests that there was a stop sign involved in the accident when in fact it was an invented detail, included in order to confuse the participants. Using this presupposition, Loftus (1975) conducted a study where the participants viewed videos of car collisions and following this, the participants were asked about the speed of car involved in the collision. Participants were split into two groups, 72 participants were asked about how fast the car was going when it turned right and 75 participants were asked how fast the car was going when it ran the stop sign. As stated earlier, detail about the stop sign was purposefully fabricated in order to presuppose the existence of a stop sign in the video. The last question given to participants was the same for the two groups: they were asked whether they saw a stop sign in the car collision. The results have shown that 53 % of the participants that were asked about the stop sign in the first question recalled seeing the stop sign in the last question where they were asked 'Did you see a stop sign for Car A?'. On the other hand, only 35 % of participants that had been asked about the speed of car when turning right recalled seeing the stop sign.

In 1975, Collins and Loftus proposed a model (which is in line with the theory of reconstructive memory proposed by Bartlett (1932), as introduced in section 2.3.) consisting of two main operations employed when memorising information. These are (i) the acquisition of information and (ii) the retrieval process. In the acquisition stage, the individual perceives a visual stimulus from the visual field. According to this model (Collins and Loftus, 1975), the visual stimulus is then stored and organized in memory according to 'nodes' or 'points'. The nodes represent different concepts in a semantic network, which consists of links between different conceptual nodes (Collins and Loftus, 1975). Loftus (1975) points out that the acquisition of new information into memory could be influenced by previous events and memories already stored in the brain. The formation of a new memory may be dependent upon prior information which has the ability to add details and alter true recollections. This relates to previous claims of Bartlett (1932) that memory is a reconstruction of an event based on the current situation and prior experience.

More evidence supporting the idea of the misinformation effect comes from a study by Loftus et al. (1978) where participants were exposed to detailed slides of a car accident. Half of the participants viewed slides of a car driving next to a stop sign, and the other half viewed slides of a car travelling towards a yield sign. The participants were then given a questionnaire in which one of the questions suggested the appearance of a sign that had not been presented in the slides. This was given to half of the participants, while the rest of the participants received a question about the sign they have definitely seen. The questions were either about a stop or yield sign, depending on which sign the participants were shown in the study phase. One week later, participants were given a forced yes-no recognition task in which one of the questions was to identify whether a presented picture of either a stop sign or a yield sign was previously seen in the initial slide presentation. The results showed that 71 % of correct pictures that were presented were correctly recognised as previously seen, while 70 % of non-presented pictures were falsely recognized as seen before (Loftus et al., 1978). This important finding shows that participants were not able to distinguish between presented and non-presented items. Loftus et al. (1978) argued that such a high rate of false alarms may be a result of demand characteristics. To elaborate, as the participants are presented with suggestive information during the study phase, they might feel obliged to answer that they have previously seen it as they believe this must be true instead of actually having the memory of it as a result of previous suggestion. However, in the latter experiment, Loftus et al., (1978), also showed that even if the participants are given a thorough explanation of the nature of the study, and are given a chance to answer what they remember seeing ***and*** also what was suggested to them, they still make errors. This shows that suggestibility can influence memory.

As stated in the beginning of this section, the misinformation effect is an example of retroactive interference, which is a distortion of encoded memory through interference of newly encoded information (Dewar et al., 2009). Time between encoding of information in the memory and the subsequent recall of that memory is filled with acquisition of new information from different sources. Retroactive interference theory (Muller and Pilzeker, 1900; in Dewar et al., 2007) claims that the learnt information undergoes interference from new information obtained and therefore new 'false' memories are acquired in the time between the encoding of original information and recall of that information. Early memory experiments have demonstrated the effect of interference (Skaggs, 1933; Muller and Pilzecker, 1900; in Dewar et al., 2007) by comparing the recall accuracy between conditions where either (i) the encoding of information was followed by an unfilled time interval where participants did not perform any task or (ii) a filled condition where the time interval between information encoding and recall was filled with a task (e.g. reading a list of random syllables aloud with the aim of encoding further distracting information to memory).

2.5 Deese-Roediger-McDermott (DRM) paradigm – false recall in word lists

Deese (1959) was the first to propose a method of testing false recall in word lists. In his study '*On the prediction of occurrence of particular verbal intrusions in immediate recall'* (Deese, 1959), he introduced a simple method of inducing false recall of critical lures. An example of a word list (words that the participants were required to remember) would be *thread, pin, eye, sewing, sharp, point, pricked, thimble, haystack, pain, hurt, injection* and an example of a critical lure would be a *needle*. Participants were not presented with the critical lure at any point of the experiment. However, Deese (1959) found that presenting these word lists and the consequent free recall of the word list items led to false recollection of the critical lure. This demonstrates how easy it is to induce false memories of words.

In 1995, Roediger and McDermott replicated Deese's (1959) findings in two experiments. In a modified procedure, Roediger and McDermott (1995) included six lists of words associated with a word, for example, *chair* (based on Deese's ideas) and following that, gave a 42-item recognition questionnaire to participants (consisting of 12 presented words from the original list and 30 un-presented words). The recognition questionnaire consisted of originally presented words from the six word lists and in addition, three types of critical lures: (i) words of strong association with the originally presented words (e.g. armchair), (ii) words with weak association (sofa) and (iii) words unrelated to those presented in the original list (e.g. floor). The study showed that participants not only formed false memories of non-presented words on the original list but recalled them at the same level of accuracy as the presented words (both critical lures and presented word recalled at the same level of probability of .40) (Roediger and McDermott, 1995). The high level of false recall was only present for the words strongly associated with the originally presented words, while the recall for weakly or not related words was much lower. The results have also shown a strong primacy effect, meaning that the words from the original list that were presented in the beginning were recalled with more accuracy than words located in the middle or end of the list (Roediger and McDermott, 1995). Additionally, in the second part of the experiment Roediger and McDermott (1995) asked participants to rate how confident they are about each recalled item being in the original list. The ratings were interesting. The results indicated that the confidence rating of previously seeing the critical lures in the original list was equal to the ones that were actually presented.

In the second experiment Roediger and McDermott (1995) then investigated the conscious recollection of critical lures by asking participants to identify whether they 'Remember' that they have seen the item in the original list or that they 'Know' that it was presented there. This became the Remember-Know-Guess (R-K-G) paradigm and is still widely used as a tool to assess the conscious nature of memory recollection (Gardiner et al., 1996). The 'Remember' judgements are used in relation to information that is consciously remembered, and the individual is able to remember full details and thoughts that they had at the time that the information was presented. The 'Know' judgements are thought to be recollections that seem familiar but yet the individual is unable to recall any qualitative details about the experience. Interestingly, Roediger and McDermott (1995) found that most of the critical lures recalled as previously seen items on the list were recalled with the

‘Remember’ response suggesting a conscious recollection and vivid memory for that word (Roediger and McDermott, 1995).

A recent study by Bergert (2013) proposed that it is possible to eliminate the false recall effect in the Deese-Roediger-McDermott (DRM) word lists by increasing the co-operation between the right and left brain hemisphere. In her experiment, Bergert (2013) gave a word list related to non-presented critical lures to participants and tested their recollection of critical lures among studied words and new words (neither presented nor related). During the study and test phase, each of the hemispheres was exposed to either study (where they encoded the words) or retrieval. In order to achieve this, participants' eye gaze was monitored by an eye tracker, and words were displayed vertically. The results have shown that false recall of the critical lure was significantly decreased if the words were studied by the right hemisphere and retrieved through left hemisphere. Bergert (2013) suggests that such effect is present due to increased conservative response tendency caused by the interaction between the brain hemispheres.

The spreading activation theory is a cognitive theory that has been proposed to explain the false recall effect in the DRM paradigm. This will be introduced now.

2.6 Cognitive theories of memory errors

2.6.1 Spreading activation theory

According to the spreading activation theory, all the memory processes are operated in cognitive 'units' which consist of 'unit nodes' and 'sets' of elements of a specific memory (Anderson, 1983). Each new cognitive unit that is formed is placed in working memory (WM) (Anderson, 1983). The basic assumption of encoding is that information in WM is transferred into information in LTM. After the memory is encoded, the already existing trace does not disappear, but is subject to degradation over time. In the process of retrieval, the already available memory trace in WM is traced back from the LTM and the contents of both traces overlap. The strength of the trigger from WM determines the strength of spreading activation and is always the source of that activation. The spreading activation theory has been demonstrated in several priming experiments, where the prime words activate not only the memory for the specific word but also for words semantically related to those presented (e.g. Bodner and Masson, 2003; Balota, 1983).

For example, Underwood (1965) presented 200 words to participants who were required to recognize whether each presented word had been shown previously in the presentation. Some of the presented words were critical items (lures), associated with the words in the original list and some had no association. Those words that were associated were falsely recognized as previously seen more than critical items that had no association to the previously presented words (Underwood, 1965).

2.6.2 Source Monitoring Framework (SMF)

Correctly remembering the source of information is an essential ability for normal memory functioning. The term source monitoring refers to processes needed in order to recover the origin of a given memory (Johnson et al., 1993). Failure to correctly attribute the source of a memory can lead to serious consequences (for example, imagining having taken medication instead of actually doing it). Johnson et al. (1993) proposed a framework through which memory is remembered according to its correct source. The SMF is often used as a theory explaining various memory distortions, for example, SMEs, misattributions, the misinformation effect, cryptoamnesia (memory bias when a person falsely recalls information as self-generated, for example writing a song or a written document), false memories, imagination and OI errors.

The process of source monitoring depends on many aspects related to the characteristics of a given memory. For example, memory rich in perceptual detail and visual characteristics is more likely to be judged as a 'real' memory than memory in which characteristics are based on feelings or thoughts present at the time of experiencing an event. These characteristics enable an individual to make better decisions about the source of information. If the visual and perceptual details are available, the source is more likely to be judged as real or external (in the outside world) because these characteristics are more likely to be derived externally rather than internally (as in the case of thoughts or feelings, poorer in perceptual detail) (Johnson et al., 1993). Two main judgement processes are involved in making source monitoring decisions, namely automatic and controlled (Landau and Marsh, 1997). Automatic judgements, also called heuristic, are those that engage visual and perceptual details in order to make the decision about the source of memory. This is a type of source monitoring judgement that is most often used when recalling a memory. The controlled, also referred to as the systematic judgement process, as described above, engages the qualitative and sensory detail about a given recollection. For example, when remembering an event, all of the available information related to it is assessed as potentially originating from a given source. This type of monitoring judgement is used sporadically, usually requires more time and is more susceptible to distortions (Landau and Marsh, 1997).

The SMF describes three types of source monitoring, (i) reality monitoring, (ii) external monitoring and (iii) internal monitoring. Reality monitoring, also called internal-external monitoring, refers to the processes underlying the ability to discriminate between the source of memories derived either externally (e.g. observed events) or internally derived (e.g. thoughts or dreams) (Johnson et al., 1993).

External monitoring refers to events only perceived in the outside world. An example of this type of monitoring would be remembering the place where you first met a close friend (Johnson et al., 1993). On the contrary, internal monitoring processes differentiate between internally generated information, for example, whether one has only thought about something or has in fact said the information aloud (Johnson et al., 1993). The inflation effects investigated in this thesis are examples of SMEs, specifically those where a failure occurs between internal and external monitoring.

2.7 Neural basis of memory distortions

Since the development of brain imaging techniques, memory distortions have been studied by cognitive neuroscientists. Three main approaches have been employed in this field. These are (i) neuroimaging (functional Magnetic Resonance Imaging (fMRI) and Positron Emission Tomography (PET) scans), (ii) electrophysiology (Event Related Potentials (ERPs)) and (iii) neuropsychology (case studies of brain damaged patients). Each of the approaches will be introduced now.

2.7.1 Neuroimaging studies of memory distortions

One of the first studies applying neuroimaging techniques to studying memory distortions used PET to compare brain activity during true and false recognition of words presented using the DRM word lists (Schacter et al., 1996). In the experiment, Schacter et al. (1996) gave participants an auditory presentation of 20-word word lists containing words that were semantically related to a non-presented critical lure (a non-presented word sharing semantics). Following this, participants were given a PET scan. Whilst being scanned, participants were instructed to categorise the words they were hearing as 'old' (heard in the first part of the experiment') or 'new' (heard for the first time). The presented words consisted of the words that were (i) previously shown to them in the lists, (ii) critical lures and (iii) additional words that were neither presented before nor were in any way related to the originally presented word lists. The behavioural results showed, as expected, that participants formed a significant number of memory errors for the critical lures, misattributing their source as originally presented in the first word list presentation (Schacter et al., 1996).

The results of the PET scans revealed increased blood flow in the medial temporal lobes (MTL) for both recognition of true words, and critical lures. Schacter et al., (1996) found increased activation in the temporoparietal regions (that have previously been shown to be involved in the processing of auditory stimuli (e.g. Howard et al. 1992, Paulesu et al., 1993)) for the true recognition but not for the false target recognition. This indicates the memory for the auditory aspects of the words that participants have heard in the first part of the study but not for the false targets. To elaborate, the activation would only be present when recognising true words, since they have been heard previously unlike the 'new' words. These findings reflect the brain activation differences during the recall of true and false targets (Schacter et al., 1996).

Karanian and Slotnick (2014) investigated whether this difference in the activation of modality specific regions during the recall of true and false target could be a consequence of the stimuli not being sufficiently engaging at the sensory level. The researchers hypothesised that given that there is a large number of behavioural studies on memory errors that show that the misremembered information contains the same amount of sensory detail as the correct information, fMRI scans should reveal a similar level of activity for both presented stimuli and critical lures, if the information is presented in an equally engaging way in the relevant sensory areas (Karanian and Slotnick, 2014). To test whether the levels of sensory engagement are the source of the discrepancy in the previous findings on neural activation during the retrieval of true and false targets, Karanian and Slotnick (2014) presented participants with shapes, which were either moving on the screen or were stationary. During the retrieval phase, participants were presented with the shapes again and asked to specify whether, they had been moving or had been stationary in the encoding phase. The results did not support the *a priori* hypothesis, showing that the true memory movement produced greater activation in the MT+ area than the false memories (region associated with motion processing). These results further support the findings of previous research, which showed a distinction between the neural activation during recall of true and false memory and the behavioural data which suggest equal level of sensory load in the recall of false information (Karanian and Slotnick, 2014).

It is also the encoding of information that shows a distinction between true and false memories at the neuronal level. Okado and Stark (2005) demonstrated that the neural activity during the encoding of original true information and false information can predict the latter recall of true and false memory. Okado and Stark (2005) showed participants eight still images in the ‘Original Event Phase’ and following that the same images with changed details within them in the ’Misinformation Phase’. For example, there would be an image of a man holding a DVD box in the ‘Original Event Phase’ and the same picture with a different DVD box in the ‘Misinformation Phase’. The participants’ brain activity during encoding in the two phases was studied with fMRI. Two days later, participants were given a memory test. The results revealed that increased activity in the tails of the left hippocampus and increased activity in the left perirhinal cortex during the ‘Original Event Phase’ was correlated with the increased recall of true memories. Furthermore, increased activity during encoding in the ‘Misinformation Phase’ predicted more false recall of details added in that phase. There was a significant difference in the activation of the left hippocampus tail between the true and false recall. These results show that it is possible to predict later reports of memory based on monitoring the neural activity during information encoding (Okado and Stark, 2005).

The idea of differentiated encoding and prediction of true and false memory recall was further investigated by Baym and Gonsalves (2010), who used an experimental set up similar to that of Okado and Stark (2005). They showed participants still images of events in the ‘Original Event Phase’, but instead of fabricating those images by adding details, they included sentences describing the previously presented images in the ‘Misinformation Phase’, some of which had the detail changed. The research further investigated if the quality of the encoding of the originally presented information could result in either lowered susceptibility or increased likelihood of developing misinformation errors, and if the misinformation presented through the verbal modality involves neural activity that could predict development of memory errors.

Baym and Gonsalves (2010) found increased activity in the left fusiform gyrus and right temporal/occipital cortex, areas associated with visual processing, during the encoding in the ‘Original Event Phase’. At the recall stage it was shown that the increased activity was correlated with the correct recall of true memories of presented information. The authors suggest that the detailed encoding procedure may result in the 'immunity' to the formation of false memory (Baym and Gonsalves, 2010) This effect has been previously demonstrated through behavioural research, showing that repetition of information during the encoding results in a weaker misinformation effect (Pezdek and Roe, 1995).

Further evidence of the MTL being involved in formation of memory errors comes from studies on the elderly, which show significant reduction of activity in these areas when compared to younger adults, during the retrieval of true memories (Dennis et al., 2007). The neural processes and the role of ageing in increase of susceptibility to formation of memory errors will be discussed in

Chapter 8, where the results of Experiment 3 ('Observation inflation in the cohort of elderly participants') study will be presented.

2.7.2 Electrophysiological studies of memory errors

In addition to neuroimaging techniques, measures of electrophysiology, in particular ERPs, have been used to investigate cortical activity underlying the formation of memory errors.

Evidence from research measuring ERPs suggests that the neural activity classically associated with visual imagery may lead to formation of memory errors directly associated with source monitoring failure (Gonsalves and Paller, 2000). Gonsalves and Paller (2000) exposed participants to an experimental task in which they were required to imagine visually common objects when presented with a word describing that object. In some of the trials a picture of an object was presented to participants instead of a cue word (the word describing the object). Participants were then tested on their source recall accuracy, where they had to recall objects that they saw on a photograph (Gonsalves and Paller, 2000). The results revealed greater parietal and occipital activation related to the memory errors, at both the encoding and retrieval phase. Furthermore, results revealed the electrophysiological difference during the encoding phase, with higher posterior potentials recorded for the words that had required visual imagination for an object, and were subsequently inaccurately recalled as actually being seen on a photograph. On the contrary, during the retrieval phase, the posterior electrodes showed greater activation for the recall of true picture memories than imagined objects, in particular true pictures elicited more positive posteriors in the occipital and parietal regions. Gonsalves and Paller (2000) suggest the discrepancy in the posterior ERPs for correct and incorrect recall relates to a different level of perceptual details that are processed during encoding and retrieval of true and false memories. There is substantial evidence from behavioural research showing that people recall more perceptual details about true rather than false memories, even when they report being equally confident when recalling false memories (Norman and Schacter, 1997).

Particularly relevant to this thesis is the work of Leynes and Bink (2002) who investigated the electrophysiology of SMEs, by comparing the ERPs elicited for encoding and retrieval of actions that were either performed or planned to be performed. In the experiment, participants performed a series of actions and also planned to perform actions. The actions to either perform or plan to perform were randomly chosen from a pool of 111 actions. Examples of the actions used were 'bend the wire' or 'crack an egg'. Following this, the ERPs were measured during a source memory test where participants were presented with a list of originally (i) performed, (ii) planned to be performed actions and (iii) novel actions, neither performed nor planned in the test phase. They were then asked to recall which of the actions they had **performed** in the first phase of the experiment. The results revealed that underlying cortical activity differed for the performed and planned to be performed actions. Performed actions triggered more positive activity in the right frontal sites (frontal lobe) suggesting that action execution triggers more sensorimotor experience than planned to be performed actions, which elicited greater negative posteriors at the parietal sites (Leynes and Bink, 2002). However, the planned to be performed actions were more likely to be misattributed as performed actions than the novel items. This study shows that although it is possible to form source memory errors as a result of planning to perform an action, the advantage of sensorimotor experience elicited through action performance enhances the correct recall of the performed actions (Leynes and Bink, 2002).

2.7.3 The neuropsychology of memory errors

Much evidence of underlying brain structures responsible for memory error formation has come from case studies on patients with brain injuries. Schacter et al. (1996a) describes a case of patient BG who made more memory errors after suffering an infarction to his right frontal lobe. Patient's lesions covered the central sulcus, motor and premotor cortex, rostral precentral gyrus, part of postcentral gyrus (inferior frontal tip of the central sulcus). The lesions also affected inferior frontal gyrus and the upper Sylvian fissure was destroyed. During a series of experiments, BG showed higher false recognition than control subjects, after being asked to categorise previously presented and unrepresented words as either 'Remembered', 'Known' or 'New'. Schacter et al. (1996a) found that BG made almost three times as many false recognitions for unrepresented words during encoding than control participants and also found that patient BG was more likely to recall unrepresented words with 'Remember' responses than control participants indicating that his confidence levels were high. As discussed in section 2.5, research on R-K-G recollection suggests information recall with these responses represents different types of recollection. ‘Remember’ consists of conscious and detailed recollection of information while ‘Know’ is undetailed recollection based on the feeling of familiarity. This suggests that patient BG not only mistakenly remembered the non-presented words in the retrieval phase but also formed a conscious false recollection of the qualitative details associated with those words. The same pattern was seen in different experiments within the study, when BG's recollection was compared for novel words and words not associated to the presented words (Schacter et al., 1996a). However, Schacter et al. (1996a) found that it is possible to eliminate the false recollection for BG by manipulating the nature of the words presented. When BG was presented with a list of words belonging to one category in the encoding phase and then with a list containing a new word categorically unrelated at the retrieval phase, it was found that BG did not form any false recollections. Schacter et al. (1996a) argue that BG's tendency to form false recollections resulted from impaired frontal lobe functioning which is usually associated with categorising information and rejecting the irrelevant information (e.g. Conway and Rubin, 1993; Shimamura et al., 1995). The initial poor encoding of the words seen in the study phase may also result in the inability to then retrieve the correct information. Encoding is also supported by frontal lobe which in this case is impaired in BG (Schacter et al., 1996a).

The tendency for increased formation of memory errors has also been demonstrated through studies on participants suffering from closed head injuries (CHI) (Ries and Marks, 2006). In comparison with control participants, twenty CHI patients remembered fewer actual items that were presented to them assessed with the DRM word list paradigm. CHI patients also made more false recognitions than control participants for non-presented semantically associated critical lures. Additionally, CHI patients were found to report more confidence in recalling the critical lures as actual presented words than control subjects. The results suggest that patients with CHI have increased susceptibility to develop false memories and although the results are only behavioural, previous research such as the study of BG by Schacter et al., (1996a) shows that patients with frontal lobe damage demonstrate similar susceptibility to memory errors, and frontal lobe islikely to be damaged during CHI (Ries and Marks, 2006).

2.8 Highlights

- Different types of memory classifications are distinguished, usually depending on the duration of memory, characteristics and type of storage.
- False memory research demonstrated the malleability of memory by studying the misinformation, suggestibility and presupposition’s effect on memory (Loftus and Palmer, 1974; Loftus, 1975).
- False memory research proposes the memory is a reconstructive process (Collins and Loftus, 1975).
- False recall of non-presented words has been widely studied in word list paradigms (DRM paradigm) (Roediger and McDermott, 1995).
- Two main cognitive theories of SME are Spreading Activation Theory and SMF.
- SMF refers to processes needed in order to recover the origin of a given memory (Johnson et al., 1993).
- False memories and SMEs have been studied in brain imaging, electrophysiological and neuropsychological studies.
- Brain imaging studies suggest that true and false memories are processed differently on the neuronal level (Okado and Stark, 2005; Karanian and Slotnick, 2014).
- ERP studies suggest the retrieval of true and false memories elicits a different electrophysiological activity (Gonsalves and Palmer, 2000; Leynes and Bink, 2002).
- Neuropsychological research shows that susceptibility for forming memory errors is linked with frontal lobe damage (Schacter el al., 1996a; Ries and Marks, 2006).

Chapter 3

Imagination inflation and observation inflation

3.1 Introduction

Chapter 2 introduced different types of memory errors and provided a review of the literature showing that memories are significantly prone to interference resulting in false memory formation. This chapter will now focus very specifically on SMEs and will introduce the imagination and OI effect.

One type of SME is imagination inflation, in which imagining an event leads to it mistakenly being attributed as an actual memory (Garry et al., 1996). Imagination inflation gained interest in the 1990s when it was considered a possible factor in the formation of recovered memories of sexual abuse during therapy sessions (Garry and Polaschek, 2000). This chapter discusses imagination inflation and OI in detail. The chapter begins with an overview of relevant theories and research in the field of imagination inflation. The OI effect, which is the main focus of this thesis, will then be introduced and the relevant developments in the subject area reviewed.

3.2 Background research on imagination inflation

When trying to remember an event people often imagine it. The same process occurs with events that have never happened. Imagery has been shown to result in false memories that an event actually happened (e.g. Hyman and Pentland, 1996, Garry et al., 1996).

Hyman and Pentland (1996) conducted a series of interviews with 65 participants, asking them to describe some true events that happened in their childhood, as well as false events that they have never experienced. Hyman and Pentland (1996) ensured that the false events had never happened to participants by asking their parents prior to the experiment to specify from a prepared list of events which have happened to the participants in the past. After being instructed to imagine the events that never occurred in the past, 20.5% of participants recalled imagined events as true events. Hymand and Pentland (1996) suggested that remembering imagined events as real occurrences is a consequence of reconstructive efforts to remember an event. This leads to imagination and subsequent failure to correctly monitor the source of that imagery, and mistaking it as really happening in the past (Hyman and Pentland, 1996).

Similar research by Garry et al. (1996) used fake childhood scenarios in an imagination task and measured participants' confidence level for the likelihood that the events have occurred in the past. The results revealed that participants were more confident in recalling previously imagined events as likely to have happened in the past, compared to the events they did not imagine (Garry et al., 1996). The authors argue that due to imagination, the information may become more familiar and accessible and consequently seem more real to the participants. The trace of familiarity may then result in inflated levels of confidence for the imagined events (Garry et al., 1996).

Broader evidence from research on the imagination inflation effect leads to a conclusion that there are several factors and characteristics of information that can lead to increase in the size of the effect.

For example, Marsh et al., (2014) investigated whether perspective changing in the imagination of childhood events can influence the ratings of the likelihood of occurrence in the past. The research compared the ratings for events that were imagined from the first person perspective to the ones imagined from third person perspective. The authors hypothesised that the ratings of 'likelihood that the events happened' in childhood would be higher after imagining the event from the third person perspective. The assumptions were based on previous research on the role of visual perspective in memory recollection which claims that the older, more distant memories are more likely to be remembered from the third person perspective than from the first person perspective, which is associated with memories for more recent events. (e.g. Nigro and Neisser, 1983; Robinson and Swanson, 1993; Sutin and Robins, 2010).

Indeed, Marsh et al. (2014) found that only the events imagined from the third person perspective resulted in inflation of ratings of likelihood of occurring in the past. Marsh et al. (2014) argued that because the imagination from the third person perspective shares the phenomenological characteristics of actual memories (that are visualised from third person perspective), it increased the similarity of imagined events to the actual ones. Such familiarity between the two could then result in source confusion, and attribution of the imagined events as actual childhood memories (Marsh et al., 2014). In further experiments, in addition to asking participants to imagine childhood events from different perspectives, Marsh et al. (2014) asked participants to also imagine recent events from first and third person perspectives. The results for imagining childhood events supported previous findings, while the recent events, contrary to the distant childhood events, were rated as more likely to occur if they had been imagined from the first person perspective. This is in line with previous research on visualisation and memory (Nigro and Neisser, 1983) and also highlights the role of familiarity and availability of information in susceptibility to source confusion (Marsh et al., 2014). As the visualisation shares phenomenological properties characteristic for a given type of memory, the information is more likely to be confused as a real occurrence.

Additionally, another aspect influencing the susceptibility to form imagination inflation errors is the valence of the information and the time in which the imagined event is placed. Sharman and Barnier (2008) have shown the imagination inflation errors to be increased when the participants were asked to imagine positive life events compared to negative events. Also, the imagination inflation errors were more likely to be made for the events that were imagined to have happened in the recent past (adulthood) compared to the distant past (childhood) (Sharman and Barnier, 2008). Participants might have assessed the positive imagined events that supposedly happened in their adulthood as true memories because they seemed to them to be the most plausible and contributed to their own self-image (Sharman and Barnier, 2008).

Horselenberg et al. (2000) looked at individual differences in relation to the imagination inflation effect. Their study replicated the results of previous studies on imagination inflation, indicating that the memory misattributions are significantly higher when preceded by imagination than when compared to control condition (no imagination). Additionally, Horselenberg et al. (2000) found that this effect is particularly inflated for participants who displayed higher imagery abilities (as found using a personality test). The results suggest that individuals with more developed imagery abilities may be prone to develop imagination inflation errors (Horselenberg et al., 2000). Horselenberg et al. (2010) also investigated whether the social desirability personality trait could predict heightened imagination inflation errors (as was previously suggested by Sharman and Barnier (2008)). However, this factor was not found to be a predictor of imagination inflations (Horselenberg, 2010).

A great deal of past research has focused on the aspects of information that might contribute to increased imagination inflation but there is also some research evidence suggesting ways in which the effect could be reduced. For instance, Sharman et al. (2005) showed that including source or familiarity cues in the experiment reduced the susceptibility to form errors. However, the effect was only present when the participants were given a source cue (either imagining from first or third perspective) and a familiarity cue (a plausibility questionnaire). As discussed earlier in this chapter, depending on the source of memory, different perspectives are imagined differently. Thus, recent events are more likely to be remembered from a first person perspective, while more distant, childhood events, are typically remembered from third person perspective. Different perspective taking when asked to imagine the events served as a cue in correct remembering. If the event was imagined in the perspective that matched the time of the imagined event (for example third person for distant events), this could result in reduction of imagination inflations. The familiarity cue was the plausibility questionnaire in which participants had a chance to provide a rating of plausibility for each of the events used further in the experiment. The purpose of this was to make participants aware of the familiarity for the imagined events (Sharman et al., 2005). The results demonstrated that it is possible to employ methods in order to reduce imagination inflation errors. This is particularly important in the context of the controversial notion of false memories formed during therapy sessions resulting from the suggestibility potentially employed by the therapists. Sharman et al. (2005) suggests that based on this knowledge, guided imagery therapy should use examples that make the source of imagined information distinct, in order to avoid source confusion errors and misattribution of imagined events as real memories. More applications of imagination inflation research will now be discussed.

3.3 Applications of imagination inflation research

The controversy surrounding instances of recovered memories of sexual abuse in the past decade has provided impetus for research on false memories. Often imagination techniques are used as a tool during those therapeutic sessions (Leavitt, 1997).

For example, cognitive behavioural therapy uses imagination as a tool in tackling anxiety disorders such as phobias (Amiri and Dariyabari, 2013). Often through imagination of the feared object or a situation, one is able to get comfortable with the idea of it. Although effective (Hofmann et al., 2012), such imaginative sessions may lead to actually remembering a positive encounter with the imagined object and misremembering it as an actual experience.

Special care should be taken as research on imagination inflation has demonstrated how easy it is to form a false memory based on brief imagination (Garry et al., 1996). In addition to the techniques applied during therapy sessions, many self-help resources rely on imagination (Pezdek, 2001). It is especially risky, as the individual using those techniques is doing it alone without any guidelines from a therapist. If the imagination is used, one must make an effort to establish the source of the imagination in order not to be confused with reality.

3.4 Criticism of imagination inflation research

There is critique regarding the misinterpretation of statistical results produced by imagination inflation research. The previously discussed research by Garry et al. (1996), which suggested that brief imagination of events results in imagination inflation errors and increased confidence that they actually happened was criticised by Pezdek (2001) as really being a statistical artefact of regression toward the mean. Pezdek (2001) suggested that the inflation of confidence ratings of imagined events was not actually the imagination inflation effect and memory distortion but a failure to interpret the statistical results correctly. The results of Garry et al. (1996) were replicated by Pezdek (2001) showing the same pattern of results. Similarly as in the results of Garry's et al. (1996) study, the confidence for events that were initially rated as low increased between part one and part two of the experiment, and conversely ratings that were high in the first part of the experiment decreased in the second part. The pattern was the same for the events that participants did not imagine. Based on this research, Pezdek (2001) suggested that the results do not indicate that the inflation of memory errors in imagination inflation research is actually a memory error, but is a misinterpretation of statistical results. Thus, it should not be used as evidence that barely thinking about an event can result in false memories of it.

3.5 Observation inflation effect – remembering observed actions as self-performed

The OI effect is a relatively novel type of source memory error. The effect has been proposed to be a failure in source monitoring, where observed actions are misattributed as self-performed actions (Lindner et al., 2010).

An example of OI error would be observing someone taking medication and later remembering taking the medication oneself. This SME could result in some undesirable consequences.

In sections 3.1-3.4, the plausibility of imagination being attributed as one's memory was demonstrated in supporting research. Since observation of actions is something people engage in on everyday basis, and it has been shown to elicit motor activation similar to when the action is actually performed (Rizzolatti et al., 1996); source monitoring errors could be expected to occur between observation of action and self -performance.

The OI effect, as far as I am aware, has only been researched directly in four studies until now (Lindner et al., 2010; Schain et al., 2012; Lindner et al., 2012; Lindner and Davidson, 2014).

Drawing on the imagination inflation effect, Lindner et al. (2010) tested if observed actions can be misattributed as one's own memory of self-performance. In their first study on OI, Lindner et al. (2010) tested the OI in two phases. In the first phase participants either only read statements describing an action or performed the described actions. In the second phase of the experiment, the participants were required to either (i) observe an action, where 10 actions were shown, each twice during the presentation on average; (ii) imagine an action, where participants were required to imagine themselves performing an action described in the action statement; (iii) generate, where participants were asked to unscramble a fragmented version of the action statement; or (iv) read an action statement repeatedly. After two weeks, the participants were tested on their memory in a source memory test, where they were required to specify which of the actions from the experiment they had **performed**. The results revealed both an imagination inflation and observation inflation effect were present in the experiment. Lindner et al. (2010) therefore demonstrated that it is possible to falsely remember observed actions as self-preformed.

Additionally, Lindner et al. (2010) showed that the OI effect is not caused only by poor source monitoring abilities, such as when an individual does not pay enough attention to the source of memory. In another experiment within Lindner's (2010) study, a robust OI effect was found when participants were explicitly instructed to pay attention to the source of the presented actions and also when they were 'warned' about the OI effect. Interestingly, and central to the remainder of the investigations of this thesis Lindner et al. (2010) explain the OI effect in relation to mirror neurone theory (which will be introduced in detail in Chapter 6). Lindner et al. (2010) suggests that shared motor activation during observation and execution of actions results in a source confusion between the two. The OI effect was also found in other research: (i) Schain et al., 2012, which will be discussed in Chapter 6; (ii) Lindner and Davidson, 2014 – discussed in Chapter 8 and (iii) Lindner et al., 2012 – discussed in Chapter 11.

3.6 Summary of the chapter

This chapter introduced the concept of imagination inflation and OI. The presented research has demonstrated that it is possible to form memory errors after imagining an action or event taking place. The OI effect draws on the imagination inflation research and demonstrates that a brief observation of action leads to remembering that action as self-performed. Given the novel hypothesis of Lindner et al., (2010), that mirror neurones could underlay an OI effect, and the aim of the thesis, the next chapter will introduce motor cognition, motor memory and mirror neurones.

3.6.1 Highlights

- Imagining action can result in SMEs and remembering the actions as self-performed (Garry et al., 1996) (imagination inflation effect).
- Observation of actions can result in memories of self-performance (OI) (Lindner et al, 2010).
- OI has been proposed to be a result of failure in source monitoring facilitated by possible involvement of mirror neurones

Chapter 4

Motor cognition, mirror neurones and action imitation

4.1 Introduction

The aim of this chapter is to discuss the concept of motor memory and motor cognition. The discovery of mirror neurones (Gallese et al., 1996) revealed that observation of actions can result in motor activation similar to when an action is actually being performed. In this chapter, research showing facilitation (motor priming) of action execution resulting from prior action observation will be discussed. Since the observation of actions enhances later reproduction and imitation of actions, research within this area will also be discussed, especially regarding the difference in imitation of different types of actions, central to the hypotheses of this thesis.

4.2 Motor cognition

The term motor cognition refers to a set of processes essential for the production and understanding of a person's own actions and the actions of others (Sommerville and Decety, 2006). This can include planning to execute an action, performing actions oneself, perceiving actions and understanding and anticipating actions of others. As mirror neurone theory suggests, action observation triggers overlapping brain activity similar to when the action is actually performed and cognition is a result of those mirroring mechanisms (Pulvermuller et al., 2014). Similar to "babbling" seen in children as they acquire language, the perception of actions being performed leads to a so-called 'manual babbling' and involves repetition of those actions (Pulvermuller et al., 2014). Research shows that the articulation of syllables activates brain areas responsible for articulating motor and speech areas (Pulvermuller et al., 2014).

Action observation and the mapping of motor mechanisms of observed actions into one's own motor repertoire are demonstrated through phenomena such as motor priming and also play a role in action imitation. The following section discusses these terms in more detail.

4.3 Action facilitation and imitation

Priming is a type of implicit memory in which observation of one stimulus influences the responses to a stimulus presented later (Meyer and Schvaneveldt, 1971). In the case of motor priming, studies have shown that action reproduction is facilitated by the prior observation of a similar motor action (Brattan et al., 2014). The research on motor priming supports the idea that action observation and execution share the same representational basis (Wilson and Knoblich, 2005). For example, during execution of a simple action (e.g. tapping a finger), observation of a congruent action (tapping a finger) at the same time is likely to result in facilitation of that performance. The opposite is seen if the observed action was incongruent (e.g. finger lifting), resulting in a longer time spent executing the action (Brass et al., 2001).

Brass et al. (2001) showed that reaction times for performing movements are faster when participants are presented with a video of the same (congruent) action being performed prior to execution of the movements. In the experiment, participants were required to observe videos of finger movements being performed (finger lifting or finger tapping), and following that, they were required to perform movements themselves. The movements were either congruent or incongruent with the previously observed movement seen on the video. The reaction times showed that observing congruent movements had a facilitating effect on the speed of execution (reaction times (RTs) decreased). However, observation of incongruent movements slowed down the RTs for movement execution. This shows that prior observation of simple movements facilitate its later reproduction. Importantly this suggests that action observation shares the neural representations with those involved in action execution, hypothesised to be the result of mirror neurone activity (Brass et al., 2001).

The same effect was observed in further research using a similar paradigm in an fMRI study (Brass et al., 2001a). As in Brass et al. (2001), congruent and incongruent movements were shown to participants (on video frame sequences), however, participants were instructed to perform predefined (either finger lifting or finger tapping) movements at the same time as watching the video frame sequences (Brass et al, 2001a). In addition to replicating this behavioural effect (decreased RTs for congruent movements and increased RTs for incongruent movements), Brass et al. (2001a) also found that the prefrontal cortex is involved in suppressing the tendency to imitate the observed action.

In addition to having a facilitating effect on action imitation, observation of motor action may interfere with the executed action (Kilner et al., 2003). In a study by Kilner et al. (2003) participants were instructed to perform horizontal or vertical movements with their arms whilst observing congruent or incongruent movements performed by either humans or robots. Interestingly, in contrast to the previous studies discussed above, it was found that **interference** was present when the participants performed and observed the same actions simultaneously (the congruent condition). However, the interference in performance was present only when the participants observed human stimuli and not when the action execution was simultaneous to the observation of a robotic hand. These findings suggest that action observation and action execution activate the same motor areas, which in turn causes the interference and impairment in the execution of actions. Kilner et al. (2003) hypothesised that simultaneous activation of motor areas when action is observed and performed leads to a ‘competition’ in activation of which the result is interference in the produced motor output.

This effect could support the claim that the mirror neurones are activated when an individual is performing an action as well as when they are observing others performing the same action. The results of these studies provide evidence for two behavioural effects where (i) observation of a congruent action before execution of a similar action **facilitates** the action execution (Brass et al., 2001, 2001a) and (ii) the interference effect, when simultaneous observation and execution of congruent action leads to interference and impairment of the action that is being executed (Kilner et al., 2003).

Similarly, Press et al. (2007) hypothesised that imitation of actions will be primed following the observation of biological stimuli (for example a human hand) but the effect will be decreased if the action is imitated after observation of a movement executed by a robotic hand. According to Press et al. (2007), facilitation of action imitation is a consequence of mirror neurone activity, and the effect of priming should be advantageous after observation of human movement because of years of sensorimotor experience and observation of human actions. This is contrary to experience of observation and imitation of actions in non-humans of which one has little experience. However, Press et al. (2007) found that exposing participants to brief sensorimotor training with the robot can in fact enhance the imitation of robotic actions. In the experiment, participants were presented with four different types of stimulus (i) human stimuli, (ii) robotic stimuli, both types subdivided into two subgroups, (i) naturalistic and (ii) schematic representations of a human and robotic hand. See Figure 4.1 for examples of the stimuli used in this study.

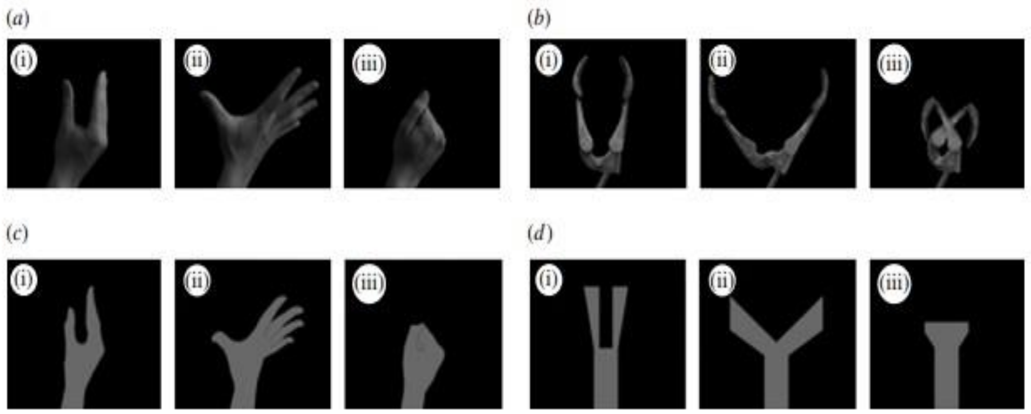


Figure 4.1 – Example of stimuli used by Press et al. (2007). *(a)* human natural stimuli, *(b)* robotic natural stimuli, *c)* human schematic stimuli, *(d)* robotic schematic stimuli.

In the experiment, participants were required to observe movements being performed by human or robotic stimuli and following that, they were required to perform a movement either compatible or incompatible with the previously observed movement. The results of the experiment showed that participants' responses were faster for trials in which they previously observed compatible movements compared to the incompatible movements. Moreover, the movements were imitated better when the participants had previously observed the movements being performed by the human stimuli, both naturalistic and schematic, than when they observed movements being performed by the robotic stimuli (Press et al., 2007). However, a facilitation effect was still seen for compatible movements in the robotic stimuli. As stated above, these results could be explained as an effect in which using information from a previously acquired motor memory emerging from observation of humans, unlike the novel robotic stimuli.

Similarly, Press et al. (2006) showed a disadvantage in responding to robotic stimuli compared to human stimuli in congruent and incongruent trials despite participants' rating of animacy for given stimuli. For example, when participants were asked to perform a predefined movement (participants were told which movement to perform before the trial. e.g. hand opening or hand closing) and the execution was preceded by observation of either robotic or human hand movements, the response speed after observation of the human hand was faster than for the robotic hand (Press et al., 2006).

The same pattern of response to previously presented human and robotic motor stimuli was found by Press et al. (2005) in an electromyography (EMG) study, showing that both human and robotic compatible stimuli resulted in faster RTs than incompatible stimuli. The participants were supposed to perform a pre-specified movement (either open or close hand) simultaneously with the onset of actions on the screen (either human or robotic stimuli). However, even though the motor priming was still present for the robotic stimuli, the magnitude of the effect was significantly higher for the human stimuli, where the actions were imitated faster (Press et al., 2005).

4.4 Motor memory

Motor memory is memory for motor skills, for example riding a bicycle, playing an instrument, writing or simple reflexes (Krakauer and Shadmehr, 2006). Motor memory is a form of procedural memory, which is implicit memory of how to perform various tasks (Nudo, 2008).

Formation of motor memories usually involves repetition of a motor task. When a task is performed, this action execution is stored in STM. Repetition of the task then allows the information to then be stored in LTM (Sommerville and Decety, 2006).

Such encoding is referred to as motor learning and involves the activation of motor and somatosensory cortices as well as frontal and prefrontal cortices, essential for attention associated with learning a new task (Nudo, 2008). This activation decreases once the skill is learned (Nudo, 2008).

It is not clear exactly where the motor memories are stored in the brain but it has been proposed that they may be stored within networks of the cerebellum and basal ganglia (Ma et al., 2010). Motor memory is thought to be formed because of a change in synaptic connectivity that is a result of neuronal firing when the action is repeatedly executed. To clarify, when a person repeats a movement, this stimulation causes neurons in motor areas to fire, and strengthens the inter-regional connectivity of neurons, as shown in the fMRI study of Ma et al. (2010).

Brain imaging studies investigating mirror neurone activity have found the motor cortices to be associated with the mirror neurone activity, in particular the primary motor cortex, the supplementary motor area and the premotor cortex. These are the areas that are primarily associated with the control and execution of movement, however, research has shown that they are also active when one is observing an action being executed (Doyon et al., 2009). However, this evidence comes mostly from fMRI studies which remain opaque at the precise neuronal level.

The involvement of mirror neurones in formation of motor memories was suggested in a TMS study by Stefan et al. (2005). In the experiment participants were instructed to observe simple thumb movements. The TMS study found that short observation of simple movements led to kinematic motor memory similar to the memory trace triggered by the physical stimulation when the same action was performed (Stefan et al., 2005).

4.5 Mirror neurones and imitation

As discussed above, the mirror neurone system can be an important factor in action priming and imitation (Sommerville and Decety, 2006). Mirror neurones are neurones that are activated when one is performing an action as well as when the same action is observed (Gallese et al., 1996; Rizzolatti et al. 1996). Because of the overlapping neural activation of sensorimotor brain areas present in both action observation and execution, such motor matching activation can give the observer the experience of actually performing the action (Gallese et al., 1996). Thus, mirror neurones could play an important role in action recognition which is essential for the understanding of social behaviour (Buccino et al., 2004).

Mirror neurones have been investigated in both monkeys and humans with the use of various brain imagining techniques as well as direct observation on the single cell level (Rizzolatti et al., 2001; Molenberghs et al., 2009; Mukamel at al., 2010). Most of the single neurone recordings of mirror neurones come from the studies on macaque monkeys but up until now, only one study has observed such activity on the cellular level in humans (Mukamel et al., 2010). Single cell recordings are the most reliable technique of observing the mirroring activity; however, due to its invasive nature and potential risks, they are difficult to perform in humans. Most of the data on mirror neurone activity in humans come from the fMRI or TMS studies, which allow for the observation of active brain areas during action observation and execution.

The research on mirror neurones has provided scientific support for some psychological concepts proposed to explain human behaviour. For example, the ideomotor theory of imitation (Hommel and Prinz, 1997) claims that the observed stimuli are 'translated' into motor responses in the observer. This means, when one observes actions being performed by somebody else, they activate the responses in their own motor system that would be a consequence of action execution if they were the performers. This fits into the mirror neurone theory that claims that observation of actions trigger similar neuronal responses to when the action is actually performed (Iacoboni, 2009). Mirror neurones then, could explain more complex behaviour based on imitations of others, for example development of language (Perlovsky and Ilin, 2013) or empathy (Corradini and Anonietti, 2013) and play a crucial role in social cognition.

Past research on the subject of imitation has proposed that action imitation involves two main components (Sommerville and Decety, 2006). The first component is recognition of the goal of the action (for example, switching on a light) and the second is the reproduction of the action through the means in which the goal is achieved (for example, tapping the light switch with head) (Hobson and Lee, 1999; Sommerville and Decety, 2006). This ability to imitate the goal of the action and the means through which it is produced is a unique human ability that can be observed in different contexts. Research has shown that nonhuman primates do not possess the ability to both reproduce the goal and the movements necessary to imitate (Tomasello et al., 1997; Tomasello, 1999). Neuroimaging studies show that distinct neural processes are responsible for processing the goal of action and the movements through which it is reproduced when being imitated (Chaminade et al., 2002). In a PET study, participants observed a brief movement of actor's right hand manipulating a Lego block (imitation of the means of action) or were just shown a goal of the action (manipulated Lego block). Following the observation, they were required to imitate the just observed action (hand manipulation of Lego block). The results revealed overlapping activity in the cerebellum, both when the participants imitated the goal of the actions and the movements made in order to achieve the goal. However, activation was present in the medial prefrontal cortex only during the imitation of movements but not when just shown the goal of the action, and imitation of the goal of the action was characterised by distinct activation in the left premotor cortex (Chaminade et al., 2002).

Research on action imitation suggests that the goal-directed actions are imitated better because of a prior acquisition of relevant motor memories, thus priming the reproduction (Rumiati and Tessari, 2002). According to the associative learning hypothesis of mirror neurons (Heyes, 2010), the actions which one has previously been exposed to, either by performance or observation, trigger more mirroring responses than those that are unfamiliar to them (Ferrari et al, 2005). For example, pianists observing finger movements on a piano keyboard show greater activation of brain areas responsible for those specific hand-finger movements than control participants (Haslinger et al, 2005). Similarly, Calvo-Merino et al. (2006) found that ballet dancers show increased activity in the premotor cortex when observing ballet movements that they have previously performed. Such activation was absent when they observed Capoeira dance moves that they had never practised or were familiar with. This is considered to be a consequence of mirror neurone activity.

4.6 Imitation of different types of actions

Understanding actions and gestures is an essential part of human social cognition. The action has a meaning when it is goal-directed and has a specific purpose. Research has shown that people imitate actions that are meaningful better than actions that carry no meaning (Rumiati et al, 2005). The main reason for this is thought to be that actions that are meaningful are stored in LTM and semantic memory, and their encoding requires involvement of visual analysis, LTM, STM, WM and the motor system before the action is imitated (Rumiati and Tessari, 2002). The meaningful actions are stored in LTM and are recognised because of their familiarity gained from previous experience in action performance and sensorimotor learning. According to the associative learning hypothesis of mirror neurones, the actions which one has been previously exposed to, either by performance or observation, trigger more mirroring responses than those that are unfamiliar to them (Ferrari et al, 2005, Haslinger et al., 2005). Furthermore, an fMRI study showed activation of brain areas during the observation of goal-directed actions even when the objects were absent (Molenberghs et al., 2012). This supports the claim that the observation of goal-directed actions can trigger the activation of mirror neurones. This review will now look at different types of actions, in particular meaningless, meaningful and communicative.

Meaningless actions are those that are not goal-directed and are not typically performed. According to Rumiati and Tessari (2002), meaningless actions are not stored in LTM because of a lack of any previous sensorimotor learning experiences. Their reproduction therefore relies on direct encoding from the visual stimuli directly in working memory (Rumiati and Tessari, 2002). Previous research has supported this assumption, showing that imitation of meaningless actions is significantly worse than the imitation of meaningful actions, as meaningless actions rely only on visual stimulation for their reproduction (Rumiati and Tessari, 2002). See Figure 4.2 for the model of imitation proposed by Tessari et al. (2007).

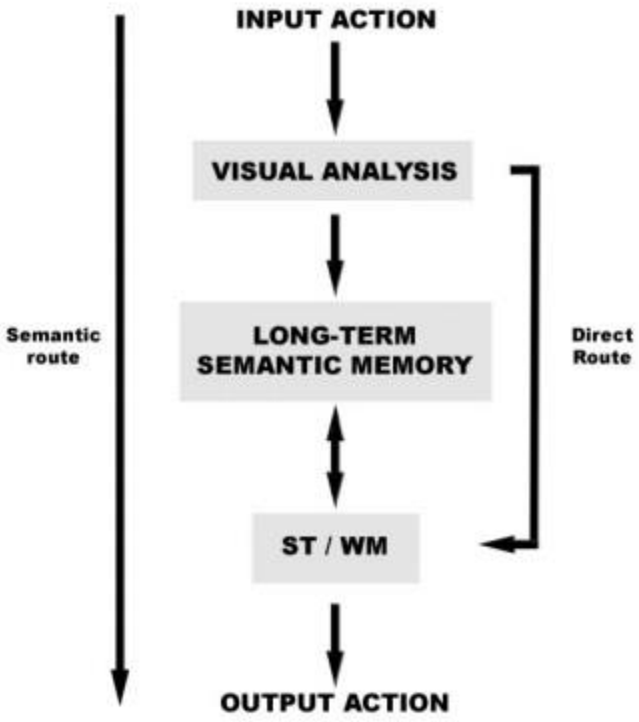


Figure 4.2 – Tessari et al. (2007), two-route model for imitation. The semantic route is used when meaningful actions are imitated and relies on visual recognition, retrieval from LTM into STM, and is reproduced as an output action. The direct route on the other hand involves only visual analysis and direct retrieval from STM/WM. This route would be used for imitation of meaningless actions.

This was further supported by Tessari et al. (2006), who found that participants performing meaningless actions create a memory trace for them in LTM. This results in imitation of meaningless actions from LTM, as in the case of meaningful actions. Additionally, Tessari et al. (2006) found that the newly learnt meaningless actions are imitated even better than meaningful actions. This might be because unlike meaningful actions, which retrieval requires discrimination from more traces of these actions, there is only one memory trace present in the LTM of the meaningless actions (Tessari et al., 2006).

Communicative gestures are meaningful when there is a recipient of these actions toward whom they are expressed. There are different types of communicative gestures, for example, communicative emblems (showing a 'thumbs up' sign), co-speech gestures (for example, moving hands to exaggerate something) and sign language gestures (Andric et al., 2013). Communicative emblems do not use linguistic features that are present in sign language gestures and also are not accompanied by speech to convey meaning like co-speech gestures (Andric et al., 2013). In order to understand meaning of communicative emblems, the brain must encode both the meaningful and symbolic expression as well as goal-directed hand actions (Andric et al., 2013). Research has shown that during the observation of communicative emblems, the brain areas that are active overlap with areas that are active during observation of both speech and grasping (Andric et al., 2013). The areas identified to be active during observation of emblems are both those involved in linguistics (the lateral temporal and inferior temporal frontal areas), and those involved in hand manipulation (parietal and premotor areas (Andric et al., 2013).

Furthermore research on imitation of different types of actions shows that meaningful communicative (intransitive) actions are imitated better than meaningful goal-directed actions (transitive) (Carmo and Rumiati, 2009). Carmo and Rumiati (2009) suggest that communicative actions do not involve objects and do not require as advanced cognitive system processing as meaningful actions, which are associated with objects. This is further supported by the fact that meaningless communicative actions are imitated better than meaningless actions that involve object manipulation (Carmo and Rumiati, 2009).

4.7 Summary

Action observation can result in similar neuronal activation as that seen when the action is actually performed (Ferrari et al., 205). The discovery of mirror neurones has provided understanding of mechanisms involved in social cognition, action understanding and action imitation. By observing and performing the actions, humans are able to form motor memories and understand their own actions and actions of others. Research shows that actions are processed and imitated differently, depending on their type (Rumiati and Tessari, 2002; Tessari et al. 2006; Tessari et al., 2007).

Lindner et al. (2010) proposed that mirror neurones can potentially stand behind OIs, therefore this thesis investigates this hypothesis further using different types of actions - meaningless, meaningful and communicative gestures with the hypothesis that more OIs will be made for communicative actions and meaningful actions (thought to have higher levels of mirror neurone activity). Communicative and meaningful actions have been found to elicit similar mirror neurone activity (Montgomery et al., 2007). Additionally, some research proposes that communicative emblems elicit higher mirror neurone activation than meaningful actions (e.g. Husain et al., 2012; Andric et al., 2013).

4.7.1 Highlights

- Action observation triggers similar neuronal activity to when the action is performed (mirror neurones) (Gallese et al., 1996; Ferrari et al., 2005).
- Mirror neurones are thought to be involved in motor cognition which is a set of processes essential for the production and understanding of a person's own actions and the actions of others (Sommerville and Decety, 2006).
- Studies have shown that action reproduction is facilitated by the prior observation of a similar motor action (motor priming) (Brattan et al., 2014; Brass et al., 2001; Press et al., 2007).
- Observation of motor movements has been found to result in motor memory of that movement (Stefan et al., 2005).
- Familiar actions trigger stronger mirror neurone activity than unfamiliar actions (Haslinger et al., 2005; Calvo-Merino, et al., 2006).
- Actions have been shown to be processed and imitated differently, depending on their type (Rumiati and Tessari, 2002).
- Meaningful actions are imitated better than meaningless actions (Rumiati and Tessari, 2002).
- Communicative actions show imitation advantage over meaningful actions (Carmo and Rumiati, 2009).

Chapter 5

Types of memory recollections – the Remember-Know-Guess questionnaire

5.1 Introduction

Many studies on false memory employ assessment of memory recollection type. The aim of this chapter is to discuss different states of conscious recollection of memory, measured with the Remember-Know-Guess questionnaire (R-K-G) (Gardiner et al., 1996). The questionnaire allows the participants to decide on the type of the recollection they have for a particular memory, depending on the strength of the memory trace. This can include the level of detail they are able to recall about it or feelings of familiarity. Given OIs can be considered a type of 'false memory', or at least a SME, the type of recollection responses given by participants were recorded in the experiments of this thesis, in order to explore the type of recollection participants had for the OIs formed.

5.2 Investigating the type of memory recollection – Remember-Know-Guess responses

The R-K-G paradigm is a methodology used to investigate the conscious recollection of tested stimuli. The paradigm aims to determine the strength of a memory trace (Gardiner et al., 2002). This methodology is especially useful in false memory and false recall studies (Roediger and McDermott, 1995).

The Remember-Know procedure (without 'Guess') was originally proposed by Tulving (1972) who developed it as a technique to assess and distinguish between episodic and semantic memories. Episodic memory refers to the memories of oneself at a specific place and time and is thought to be more related to the 'Remember' response (Tulving, 1972). Semantic memories on the other hand are not self-referential, and are linked to more general knowledge (e.g. capitals of countries in the world) and are thought to be recollected with the 'Know' response (Tulving, 1972). Although the sense behind each of the judgements is still related to the original purpose, the questionnaire is currently used to measure the type of memory recollection, rather than to differentiate between episodic and semantic memory (Mickes et al., 2013).

The 'Remember' response refers to recollection of episodic memories with reference to the self. The information recollected is rich in qualitative information and is more detailed than the information retrieved with the 'Know' response. Contrary to the initial purpose of 'Know' judgements which was to investigate semantic memories without any self-reference, it is now considered an indicator of familiarity and recollection, but poorer in detail than ‘Remember’ responses (Mickes et al., 2013, McGabe et al., 2009). Thus, the ‘Remember’ recollection shows strong and conscious recollection of information about an event or item. 'Know' responses imply the existence of the item or event and are marked by feelings of familiarity (McMillan et al., 2003). ‘Guess’ responses indicate recognition but are not based on any memories; they show no recollection or familiarity of presented stimuli (Horry et al., 2010). The ‘Guess’ responses are usually included for items that are judged to have been previously seen, but the source of the memory or memory of this item is not present. The purpose of this response option is really to strengthen the R-K-G questionnaire, since the absence of the 'Guess' response option could force the responses to be judged as not remembered at all – even though there is a trace of recollection (Horry et al., 2010). Furthermore without the ‘Guess’ option the pattern of Remember-Know responses could also be incorrect as the recollections with 'Guess' judgements could erroneously be allocated to 'Know' responses instead.

5.3 Different R-K-G procedures

The R-K-G procedure differs in the number of steps it involves. The R-K-G can be carried out as (i) a one-step procedure; (ii) two step procedure and include the ‘Guess’ option or (iii) only include ‘Remember’ and ‘Know’ responses (Bruno and Rutherford, 2010).

The one-step procedure involves presenting an item to participants and asking them to specify whether they ‘Remember, ‘Know’ or ‘Guess’ that they recall the item or to classify it as a ‘new’ item (where they think that the item has not been seen previously). This type of procedure however, can implicitly suggest to participants that the items have been seen before, because they are immediately asked whether they ‘Remembered’, ‘Knew’ or ‘Guessed’ that they encountered the tested stimuli (Bruno and Rutherford, 2010).

A different kind of procedure using the R-K-G paradigm involves two steps (Java et al., 1997; Bruno and Rutherford, 2010). In the first step, after the participants have been presented with the stimuli, they are asked to decide whether each item is old or new. In this case, old and new refers to whether the item presented in the retrieval has been encountered in the previous stages of the experiment (old) or not (new). In the second phase of this procedure, the R-K-G paradigm is then given to participants to decide whether they ‘Remember’, ‘Know’ or ‘Guess’ (if ‘Guess’ option is included in the paradigm) that they have previously encountered the item. Bruno and Rutherford (2010) attempted to compare the false recall rates between the two procedure types and found equal recognition accuracy, regardless of whether the one-step or two-step procedure was used. This means that the number of items correctly and falsely recognised as previously seen did not differ when the participants were asked with either of the two procedures (Bruno and Rutherford, 2010).

Another important factor when using the R-K-G paradigm is the type of the instruction given to participants (Geraci et al., 2009). Interestingly, changes in how the R-K-G terms are explained or defined to the participants can affect what is actually being measured. Geraci et al (2009) tested this in two experimental sessions. In the first part they presented the participants with a list of 30 items (in which half of the items were real words and the other half were non-words). The participants were instructed to memorise the words from the list. After a retention interval (approximately 10 minutes), the R-K-G instructions were read to them and the participants completed the recognition test. One week later, they were invited for another recognition test, where they were again presented with a new list of 30 words. After a testing delay following the experiment, they were given a recognition test where they specified whether they were ‘sure’ or ‘unsure’ that they saw the word in the presentation before. The results revealed that participants were more likely to recall real words with the sure response that the non-words. In another experiment within the same study, Geraci et al. (2009) used the same procedure to test the recollection but used a different set of instructions. The 'Know' responses were defined as indicators of lower confidence for recollection of particular words from the presented lists (Geraci et al, 2009).

The results of both experiments showed that the type of the instructions used in the experiments give different results in terms of the pattern of confidence reflected by ‘Remember’ and ‘Know’ responses (Geraci et al., 2009). This means that when participants were given instructions that suggested a ‘Know’ response as indicating high confidence of recollecting the tested words, the pattern of ‘Remember’ and ‘Know’ responses differed from the one of ‘sure’ and ‘unsure’ judgements. However, when the instructions suggested that a ‘Know’ response reflects a lower confidence in recalling the word as previously presented, the pattern of ‘Remember’ – ‘Know’ responses was similar to the one of sure-unsure judgements. This means, participants were more likely to recall the studied words with 'Remember' and 'sure' responses than' Know' and 'unsure' (Geraci et al., 2009). These results highlight the importance of the wording of the instructions given to participants in the R-K-G paradigm and the subsequent interpretation of the results.

Furthermore, Frithsen and Miller (2014) found dissociation in the activation within the posterior parietal cortex (PPC) when participants recalled words with ‘Remember’ and ‘Know’ responses. In the study, participants were presented with a 300 words word list and took a ‘Remember’ – ‘Know’ test while in the fMRI scanner. The results revealed that the familiarity judgements (the ‘Know’ answer) showed greater activation in the intraparietal sulcus and superior parietal lobule. Recollection (words judged as ‘Remembered') caused activation in the ventral regions, especially the inferior parietal lobule and within angular gyrus. These differences suggest a variation in the cognitive demand that is a consequence of each retrieval type (for example, self-referential processing when making ‘Remember’ judgements). The difference in activation found in the posterior cingulate cortex (PCC) can be related to patient studies, where patients with damage to the PCC show difficulties in processing the conscious experience of remembering (Frithsen and Miller, 2014). For example, some of the symptoms parietal patients demonstrate include lack of detail in their memories or lack of confidence that the recalled events actually happened (Davidson et al., 2008).

Additionally, patients with parietal damage show difficulties in the ability to perform on the R-K-G paradigm, compared to other source memory tests. This is thought to be because R-K-G relies more on the processes related to the activation of ventral PCC, as demonstrated by Frithsen and Miller's study (2014).

5.4 Summary

R-K-G questionnaire allows study of different types of memory recollections. 'Remember' judgements are associated with a conscious recollection, when one remembers qualitative details associated with the information, for example thoughts or feelings. 'Know' judgements relate to recollection that is not detailed and associated with feelings of familiarity. Contrary, 'Guess' judgements indicate that one has guessed that they encountered information or event in the past.

In the experiments of this thesis, the R-K-G questionnaire was used to investigate the type of recollection for OIs and SAIs.

5.4.1 Highlights

- R-K-G relates to different memory recollection types.
- 'Remember' recollections are associated with conscious and detailed recollection of memory.
- 'Know' responses express feelings of familiarity towards an item or event, but being unable to recall any specific details.
- 'Guess' response indicates no recollection.
- The instructions for the R-K-G paradigm can affect the meaning of collected data (Geraci et al., 2009).
- Past research showed that retrieval of words with 'Remember' and 'Know' activated different brain areas (Frithsen and Miller, 2014).

Chapter 6

The observation inflation effect – memory for different types of actions

6.1 Introduction

This first experimental chapter investigates the OI effect in a healthy young adult sample. OI is a SME in which action observation results in memories of self-performance. In this chapter, potential OI effects will be discussed as a result of the observation of different types of actions: meaningful, meaningless and communicative. Since previous research proposes that OI is a result of underlying mirror neurone activity (e.g. Lindner et al., 2010) triggered by action observation, it will be hypothesised that different pattern of OIs will be present depending on the action type that was observed, as different action types recruit mirror neurones differently (e.g. Husain et al., 2012; Montgomery et al., 2007; Rizzolatti and Arbib, 1998).

6.1.1 Observation Inflation

Lindner et al. (2010) demonstrated that it is possible to remember observed actions as self-performed and termed these SMEs as observation inflations (OIs). The first study of Lindner's (2010) on OI involved three experiments in which participants were subjected to a variety of conditions after which their memory was tested. In the first experiment of the original study, Lindner et al. (2010) exposed the participants to two conditions. In the first condition, all the participants observed videos of simple actions being performed depicted from the third perspective (i.e. performed by another person). The other conditions involved either (i) reading an action statement, (ii) performing a described action, (iii) repeatedly imagining performing a described action, or (iv) unscrambling an action statement from a fragmented version of an action statement. Lindner et al. (2010) found that the inflation effect for source memory errors was significantly higher when the participants observed and imagined the action, than if they simply read or unscrambled the word. These results demonstrated that it is plausible to form memories of self-performance by action observation (Lindner et al., 2010).

Potential causes of this effect were attributed to inattentive source monitoring processes resulting in source confusion and attribution of the observed action as self-performed. To minimise the potential influence of lax source monitoring on formation of OIs, Lindner et al. (2010) employed additional instructions to the procedure from Experiment 1. Two groups of participants were warned before the source memory test to either (i) try to remember any self-performance cues (e.g. their feelings, sounds or any specific detail about the observed/performed actions) and to pay attention to whether it was them or the actor performing the actions; or (ii) in the second condition, participants were specifically informed about the OI effect and warned to avoid making these source confusion errors. Interestingly, even with the 'warning', the results replicated the findings of the previous experiment, showing that action observation can result in memories of self-performance. Participants equally misattributed the actions in both warning conditions (Lindner et al., 2010). Although the results of this experiment would suggest that source-monitoring is not the primary reason for formation of OIs, the source memory error could still occur because action observation and performance are characterised by the same features. Lindner et al., (2010) suggested that the OI effect transpires because of motor stimulation activation taking place when observing an action that is similar to the motor activity present in the brain while the action is performed. This explanation could also account for the results of Experiment 3 by Lindner et al. (2010), that showed that more OIs are formed for actions observed from the third person perspective (the same perspective as when the mirror neurones are activated i.e. as in social interaction and observing another person) than the first person perspective (as if performed by oneself). Hence, the characteristics of observed actions could be misattributed as performed (Lindner et al., 2010).

In another study on OI, Schain et al. (2012) investigated whether OI can be influenced by discriminatory features of self and the observed actors. For example, participants observed an action being performed by an actor, and discriminatory self-other features such as face or torso were visible to them. This is unlike the study of Lindner et al. (2010) where only arms and hands were seen manipulating the objects. Since observing the actor's face can provide more cues for correct discrimination between the self and the actor, Schain et al. (2012) hypothesised that the observation of actions providing more distinct features will result in a decreased number of OIs when compared to actions not providing enough cues for self-other discrimination (when only actor's hand are visible). In order to test this, Schain et al. (2012) asked participants to either perform an action described in an action statement or read a statement describing an action and, following this, observe either (i) the action being performed by an actor where the face of the actor was visible or (ii) when only the hands of the actor were visible. Additionally, in the condition where the face of the actor was visible, participants' attention was either drawn to the actors face by the actor saying a syllable (e.g. 'aka' or 'uku') or there was no focus on the face of the actor. The results of this experiment replicated the original finding of Lindner et al., (2010) showing that OIs can be formed after short observation of actions, and provided more insight into how discrimination can vary the patterns of misattribution. Schain et al. (2012) found a higher number of OIs were formed for actions where only actor's hands were visible compared to where an actor's face was visible in the video as well. Interestingly, the OI was eliminated in the condition where participants observed actions being performed by the actor with the face visible and articulating the syllables. Schain et al. (2012) attributes this effect to source monitoring theory, which claims that distinctive features decrease the source confusion (Hashtroudi et al., 1990).

More support for the OI effect comes from Manzi and Nigro's (2008) study where correct source recall of observed and performed actions was investigated. Although the misattribution of observed actions as performed was not the primary aim of the study, the memory errors for observed actions were recorded in addition to the correct source recall. This study is discussed in detail in Chapter 10, where the recollective experience of OI is investigated.

6.1.2 Imitation of actions

Based on previous research on imitation in humans evidence suggests that actions are imitated differently depending on their type (e.g. Rumiati and Tessari, 2002, Tessari et al. 2006). As the OI effect has only recently been studied in the field of false memory research, many of its features have not yet been investigated. For example, does the type of the observed action affect the number of OIs formed?

Research on imitation of various types of actions shows disparity in imitation between different action types (Tessari et al., 2006; Rumiati and Tessari, 2002). Work by Rumiati and Tessari (2002) has shown a general advantage in imitation of meaningful actions over meaningless actions. Meaningful actions are thought to be goal-directed (for example stapling a document). However, meaningless actions are not goal-directed, and are not usually performed in everyday life (for example brushing your arm with a toothbrush). Meaningful actions are already stored in LTM and are recognised because they are well-known and familiar to participants, a consequence of executing and observing the actions in the past (Rumiati and Tessari, 2002). On the other hand, meaningless actions are not stored in LTM because of lack of previous sensorimotor learning experience and their reproduction relies on direct encoding from visual stimuli to working memory (Rumiati and Tessari, 2002). Because meaningless actions are neither goal-directed nor commonly performed/observed, there is no memory for them. Their imitation then relies solely on reproduction from STM, which results in an imitation disadvantage compared to meaningful actions, manifesting itself in a shorter imitation span and less accurate movement reproduction (Rumiati and Tessari (2002).

This is further supported by the results of Tessari et al. (2006), which show that exposing participants to meaningless actions creates a memory trace for them in LTM. The meaningless actions are then imitated through the semantic LTM route, as in the case of meaningful actions. Tessari et al. (2006) found that learnt meaningless actions are imitated even better than meaningful actions. This might be because only one memory trace for those actions is present in the LTM, contrary to the meaningful actions, for which the retrieval from LTM requires discrimination and inhibition of more representations of those actions (more representations of those actions are likely to come from prior execution/observation of those actions in everyday life) (Tessari et al., 2006).

Regarding the imitation of communicative emblems, Carmo and Rumiati (2009) found that meaningful communicative actions are imitated better than meaningful goal-directed actions. Carmo and Rumiati (2009) attribute this to the fact that communicative actions are not associated with objects and hence do not require as advanced cognitive system processing as meaningful actions. This is further supported by the fact that meaningless communicative actions are imitated better than meaningless actions that involve object manipulation (Carmo and Rumiati, 2009). The dual-route model of imitation (Rumiati and Tessari, 2002) was discussed in more detail in Chapter 3.

Furthermore, motor simulation research shows disparity in imitation of communicative emblems, meaningful and meaningless actions. Liepelt et al. (2010) investigated a motor priming effect in an experiment where participants reproduced previously presented actions. Each participant observed one action from each action type category which were (i) communicative emblems (a victory sign), (ii) meaningful (grasping an apple) and (iii) meaningless (a closed fist) performed by (i) a human hand and (ii) a wooden hand. The results revealed that motor simulation is affected by the type of action that is being observed. Specifically, the results showed that motor priming had a stronger effect on the reproduced action if the observed stimuli were human hands than wooden hands. However, this effect was only present for the communicative emblems – meaningful and meaningless actions produced a similar motor priming effect for both stimuli types. Liepelt et al. (2010) proposes that the motor simulation processes are possible when the observer is able to make out the goal of the observed action and that action seems reasonable to them. This is demonstrated in another experiment from Liepelt et al. (2010) which also tested the motor priming effect with communicative stimuli being either a human or a wooden hand depicting the action of hand shaking. Interestingly, the motor priming was not present when participants observed the wooden hand since they could not make out the goal of the action, as the action of greeting was not associated with the wooden hand. In this case, even though the action was a meaningful communicative emblem, it was judged to be meaningless because it was enacted by a wooden hand (Liepelt et al., 2010).

6.1.3 Mirror neurones and different types of actions

There is also evidence that the observation of actions results in the formation of a motor memory of performing that action (Stefan et al., 2005). This is in line with the research on mirror neurones which has demonstrated through a wealth of studies that observation of actions being performed by somebody else triggers similar activation in the brain of the observer as would be seen if the action had been performed by them themselves (e.g. Molenberghs et al., 2010; Bucino et al., 2004). For example, pianists observing finger movements on a piano keyboard show greater activation of brain areas responsible for hand movements than control subjects (Haslinger et al., 2005). Communicative hand gestures have been found to produce more intense mirror neurone activity in monkeys as well as humans than meaningless or non-goal-directed actions (e.g. Rizzolatti and Arbib, 1998; Iacoboni, 2009).

Montgomery et al. (2007) studied the brain activation during observation and execution of communicative emblems (e.g. thumbs up) and meaningful actions (e.g. stirring tea). The results of their fMRI experiment revealed similar mirror neurone activation for both types of actions in the inferior parietal lobule, frontal operculum activity and in the superior temporal sulcus. Montgomery et al. (2007) suggest that both types of actions activate the mirror neurone system to the same extent. However, it is important to note that the actions in their study did not actually involve object manipulation, but were mimed. This might have resulted in participants processing the goal-directed actions on the same level as the communicative emblems, hence the similar mirror neurone activity (Montgomery et al., 2007). In addition to recording the neural activity in the brain areas associated with mirror neurone activity, Montgomery et al. (2007) found neuronal activation in different brain areas for communicative and goal-directed actions. They found that brain activation for both types of actions significantly differed in terms of areas they activate. Object directed actions were found to activate cerebellum, putamen and premotor cortex, areas which are associated with motor behaviour. Communicative actions on the other hand, activated areas related to social cognition and theory of mind, such as medial prefrontal cortex, anterior superior temporal sulcus and temporal pole (Montgomery et al., 2007).

A great deal of research on mirror neurone activity and type of action observed comes from studies on monkeys. For example, Ferrari et al. (2003) describes communicative mirror neurones in monkeys which are neurones that are active specifically for mouth communicative actions (e.g. lip smacking or tongue protrusions). These actions are clearly linked to ingestive actions which are associated with food intake. Ferrari et al. (2003) explains that the monkey communication system might have developed from these ingestive actions, which are a central part of monkey's gestural repertoire and are familiar to them. Interestingly, human communication has also been suggested to arise from similar mechanisms, i.e. possible development of vocal syllables from lip smacking movements (Ferrari et al., 2003).

Another study by Caggiano et al (2012) found that in monkeys, a reward value attached to the object in the action that modulates the magnitude of mirror neurone activation. The higher the reward associated with the object, the bigger the activation of mirror neurones. Thus, based on the value of the object, the monkey understands the goal of the action (Caggiano et al., 2012).

More evidence on mirror neurone activation by different types of actions was found by Wriessnegger et al. (2013), who observed greater mirror neurone activation when participants observed grasping movements towards objects that were familiar (e.g. a glass of water) than abstract objects (e.g. a trapezoid). This finding suggests that even if one observes a motor action that is familiar, the objects towards which the action is executed have a strong impact on evaluating this action as either goal-directed or meaningless. In this case, the observation of grasping the abstract object did not activate the mirror neurone system to the same extent as grasping a meaningful and familiar object (Wriessnegger et al. 2013).

6.1.4 Aim of the present study

This study will investigate the OI effect for different action types. As far as I am aware, the action type that is being observed or performed has not been considered in previous studies on OI effect (Lindner et al., 2010; Schain et al., 2012). Neither of these studies specifies the type of the action used, nor does it provide a list of actions that were used in the experiments. From the examples given, it is assumed that the actions were considered meaningful (e.g. 'shake a bottle' in Lindner et al., (2010) or 'squeeze a sponge' in Schain et al., (2012)).

Based on the evidence from imitation and mirror neurone research (Montgomery et al., 2007; Husain et al., 2012; Andric et al., 2013; Rumiati and Tessari, 2002), and the fact that Lindner et al. (2010) suggest that mirror neurones may stand behind OI effect, the hypothesis is that the different types of actions will result in different number of OIs. Thus, this experiment will use three types of actions: meaningful (e.g. 'stapling a document'), meaningless (e.g. 'brushing one's arm with a toothbrush') and communicative emblems (e.g. 'thumbs up'). It is expected that the communicative and meaningful actions will produce more OIs since they have been shown to activate the mirror neurone system in humans (e.g. Husain et al., 2012). The lowest number of OIs is expected for meaningless actions as the participant will not have any previous memories for them and they are not goal-directed. Observation of non goal-directed actions shows little or no mirror neurone activity (e.g. Avanzini et al., 2012; Wriessnegger et al., 2013; Ocampo and Kritkos, 2011).

6.2 Methods

6.2.1 Participants

Thirty-five participants took part in the study. The participants were recruited from the University of Bradford (mean age = 29.15, SD = 9.64). Twenty six females (mean age = 28.16 years, SD = 9.14) and nine males (mean age = 31.86 years, SD = 11.16) took part in the experiment. The volunteers were invited to take part in the study via E-mail invitations sent out by administrative secretaries of faculties at the University of Bradford. The experiment was also advertised in the Staff briefing and weekly Student Telegram. All participants gave informed written consent. The inclusion criteria for participation consisted of no history of autism (as this may suggest an impaired mirror neurone system) and no uncorrectable visual impairments. In order to ensure the participants' anonymity, each of them was identified by a unique number. Ethical approval was given by Humanities, Social and Health Sciences Research Ethics Committee at University of Bradford.

6.2.2 Design

A within-subject design was used. The different conditions were action type stimuli, in which participants were asked to (i) observe a presentation consisting of videos of three different types of action (meaningful, meaningless and communicative) and to (ii) perform specified actions (meaningful, meaningless and communicative) that were different to those actions observed in (i). The between-subject variable was different time delay of assessing OIs (one day, one week or two weeks). The dependent variable was the number of OIs formed.

6.2.3 Materials

The stimuli used in the experiment were 30 short videos of simple actions being performed. The videos were created using a camcorder and put into a PowerPoint presentation. The actions that participants were asked to perform were written into statements and put on separate slides into a PowerPoint presentation. The time given for execution of the single action was 10 seconds and this was timed automatically in PowerPoint. The videos were preselected into three separate sets of presentations (for meaningful, meaningless and communicative) and the order of observation and performance conditions was counterbalanced across the conditions for each participant. Participants performed 30 actions in total. The actions in the videos depicted a female actor in a sitting position from third person perspective (camera facing the actor). All of the videos were performed by the same actor.

a)

b)

c)

Figure 6.1 – Screenshots from the action recordings used in the experiment: (a)

example of meaningful action perspective; (b) example of communicative emblem perspective; (c) example of meaningless action perspective.

6.2.4 Pilot study

A pilot study was carried out on 10 people to be sure that the stimuli could be classed as meaningful and meaningless (as sometimes this remains unclear). Participants saw 80 videos of actions and rated them as meaningful or meaningless on a scale of 1–10 and were asked what they thought the goal of the action was. A set of stimuli were created from these results.

6.2.5 Questionnaire

In order to measure the OIs, a questionnaire was designed. The items in the questionnaire consisted of sentences written in the first person suggesting that participant performed the action (e.g. *I opened a bottle; I stapled a document*). To recap, OIs occur when a person remembers an action that they have observed as one they have performed themselves. The sentences contained 30 actions that participants performed and 30 actions that they observed. Additionally, 20 actions that were neither observed nor performed were added to the questionnaire in order to test ‘real’ false memories (see Appendix 1 for OI questionnaire).

6.2.6 Remember-Know-Guess

The R-K-G (Gardiner et al., 1996) paradigm was adapted in order to determine the type of recollection. In the questionnaire, participants were asked to answer ‘YES’ if they remembered performing the action or ‘NO’ if they did not remember performing the action. If the answer was ‘YES’, participants were asked to decide about the type of recollection they had. They were asked to answer ‘Remember’ if they could remember qualitative details about the performed actions and ‘Know’ if they could not retrieve any specific details about the action but it seemed familiar to them. They were instructed to answer ‘Guess’, if they guessed that they performed the action. The copy of the instructions and the questionnaire with R-K-G paradigm can be found in Appendix 1. For more information on the recollective experience and R-K-G see Chapter 5 and Chapter 10 for detailed analysis of R-K-G recollection scores from the experiments of this thesis.

6.2.7 Procedure

The time of the participation was arranged with the volunteers that expressed an interest in participation after being provided with an information sheet. The experiments took place in the Psychology Laboratories in the Division of Psychology, University of Bradford. After the participants were greeted by the researcher, they were allocated to individual cubicle rooms with a computer. They were seated in front of the computer and given the information sheet and consent form. After the participants had given informed written consent and familiarised themselves with the purpose and nature of the study they were instructed to watch a video presentation of 30 actions and perform 30 actions. The order in which videos of actions and action statements were presented was counterbalanced. In the performance part, the researcher explained that they will have to perform the actions described on the PowerPoint slides. The participants were assured that they were not being observed nor recorded during the executions of actions. After the experiment was finished, the researcher arranged the time for a second session with the participants where they would need to complete the OI questionnaire. Participants came back to the Psychology Laboratories after one day, one week or two weeks from the first part of the experiment.

In the second part, participants were asked to complete the OI questionnaire after familiarising themselves with the instructions. They were encouraged to ask questions if the instructions were not clear to them. When they had completed the questionnaire, they were thanked for their participation and escorted back to the entrance by the researcher.

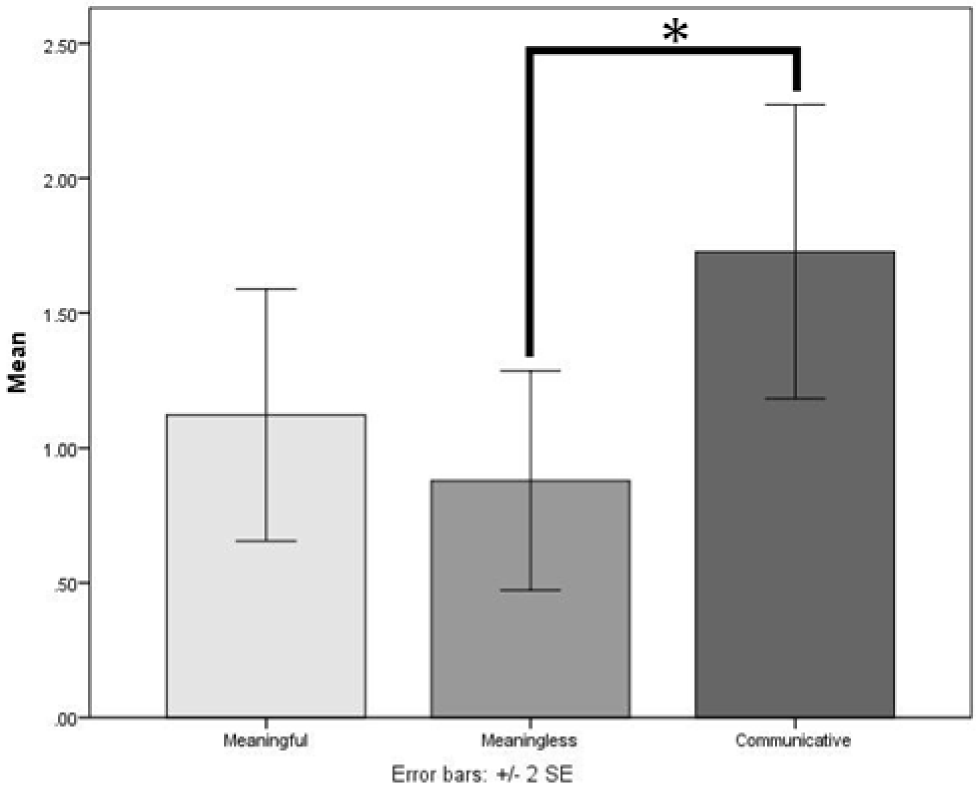
6.3 Results

The primary aim of the study was to investigate the formation of OIs as a result of action observation of different types of actions (meaningful, meaningless and communicative). OIs are the number of misattributions of observed actions as ones that were performed i.e. where participants had stated on the questionnaire that they had performed actions when they had actually only observed them.

The OIs were the actions that participant recalled with 'Remember' and 'Know' responses in the source monitoring questionnaire. The two responses were summed to create the OI variable. The 'Guess' response was not counted as an OI error (See Chapter 5 which introduces the R-K-G procedure and Chapter 10 which is dedicated to the results of the R-K-G responses specifically). See Figure 6.2 for the number of OIs formed for different action types.

6.3.1 OI in different action types

Figure 6.2 shows OIs for all action type conditions, showing that the highest number of OIs was formed after observing communicative actions. These results are from all time delays combined.



*p<0.05

Figure 6.2 – Mean number and standard errors of OIs in meaningful, meaningless and communicative conditions.

The assumption of normality has not been met for the sample conditions Standard parametrical tests were carried out alongside non-parametric test. For this section both analyses showed the same results. The parametric analysis is reported.

A 3-way (meaningful vs. meaningless vs. communicative) repeated measures analysis of variance (ANOVA) showed a significant main effect of action type, $F(2, 64) = 5.67$, $p<0.05$, suggesting that there was a significant difference in the number of OIs formed after observing different types of actions. Pairwise-comparisons revealed that there was a significant difference in the number of OIs formed after observing communicative and meaningless actions ($p<0.05$), where observation of communicative actions resulted in more OIs than observation of meaningless actions. The data did not reach a statistical significant difference for the number of OIs formed between meaningful and communicative actions ($p>0.05$) and meaningful and meaningless actions ($p>0.05$).

This shows that participants were more likely to misattribute observed communicative actions as actions they had performed themselves rather than observed meaningless actions. From these results, they were as equally likely to misattribute observed meaningless and meaningful actions as performed and communicative and meaningful.

6.3.2 OIs formed with different types of actions at different time delays

Participants completed the questionnaire at different time delays (one day, one week and two weeks). See Figure 6.3 for the number of OIs formed for different action types at different time delays.

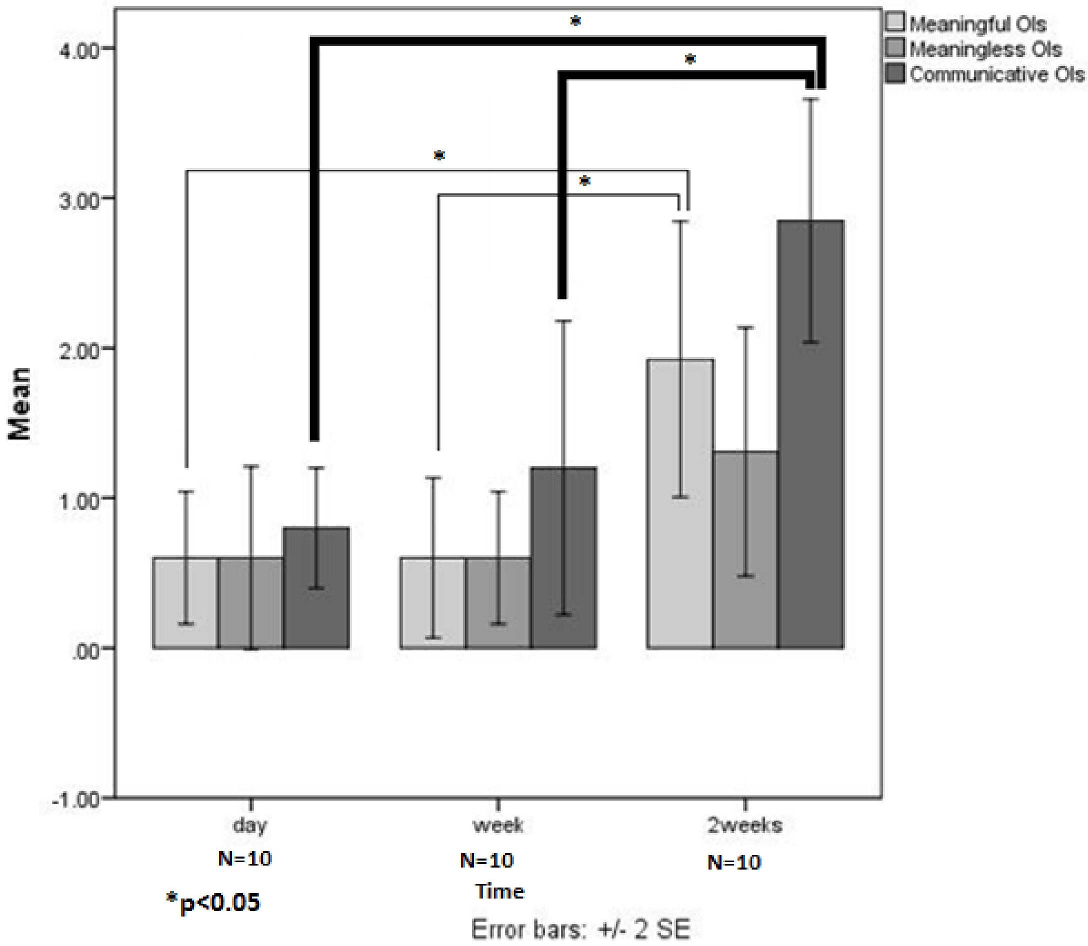


Figure 6.3 – Mean and standard errors of OI errors after different testing time delays (one day, one week or two weeks) for all action types.

The total number of OIs increases with time, (regardless of action type) especially between one week and two weeks (total of all OIs at one day = 2.0, total of all OIs after one week = 2.4, total of all OIs after two weeks = 4.8). It is interesting, (see Figure 6.3) that the mean number of OIs formed for both meaningful and meaningless actions is the same for both action conditions (0.6) after both one day and one week. Only in the communicative action condition does the number of OIs increase (one day= 0.8; one week=1.2; two weeks=2.85).

Non-parametric results are reported for this section. The analysis with Kruskall-Wallis test showed that there was a significant difference in the number of OIs formed between the three time delays, regardless of the action type, $\chi^2(2) = 10.2$, $p<0.05$. Post hoc test analysis with Mann-Whitney U tests showed that significantly more OIs were formed after a two week time delay than one day (U = 11, $p<0.05$) and one week (U = 17.5, $p<0.05$).

Further analysis with Kruskall-Wallis H test revealed that there was a significant difference in the number of OIs formed for different action types between the three time delays, $\chi^2(2) = 12.2$, $p<0.05$. Post hoc test was analysis with Mann-Whitney U tests was conducted and revealed that significantly more OIs were formed for communicative actions after (i) two weeks rather than one day (U = 13.5, $p<0.05$); (ii) two weeks than one week time delay (U = 25.5, $p<0.05$) and for meaningful actions after (iii) two weeks than one day (U = 30.5, $p<0.05$) and (iv) two weeks than one week (U = 30, $p<0.05$).

6.3.3 Other measurements

Although the primary aim is to investigate OIs, the other measurements recorded are important to report as they provide information about how easy/hard the stimuli are to remember in general. The other results were the numbers of actions that were (i) *"performed correct"*- where participants **had** performed the action according to the description of actions on the PowerPoint slides in the study phase of the experiment AND subsequently correctly recognised that they had performed the action on the questionnaire; (ii) *"performed incorrect"* – where participants indicate on the questionnaire that they had never performed the action (ticking 'no') but in fact they had; (iii) *"observed correct"* – where participants remember correctly that they have not performed the action e.g. in response to the phrase 'I shook a bottle' on the questionnaire which they had observed on the video in the study phase, participants tick 'no', and they indeed had only observed the action. The final measurement is (iv) *"false memories",* where participants remember performing an action that they neither performed nor observed. See Table 6.1 and Figure 6.4 for a breakdown of these measurements.

Table 6.1 – Other measurements for all action type conditions after different time delays.

	Meaningful				Meaningless				Communicative			
	Day	**Week**	**2weeks**	**total**	**Day**	**Week**	**2weeks**	**total**	**Day**	**Week**	**2weeks**	**total**
Performed correct	7.1	7.4	4.7	**19.2**	7.9	6.5	7.2	**21.6**	7.8	7.7	6.5	**22**
Performed incorrect	2.7	2.2	4.5	**9.4**	1.6	2.2	2.4	**6.2**	1.5	1.1	2.4	**5**
Observed correct	8.8	8.6	8.1	**25.5**	9.1	8.4	8.1	**25.6**	8.6	6.9	5.2	**20.7**

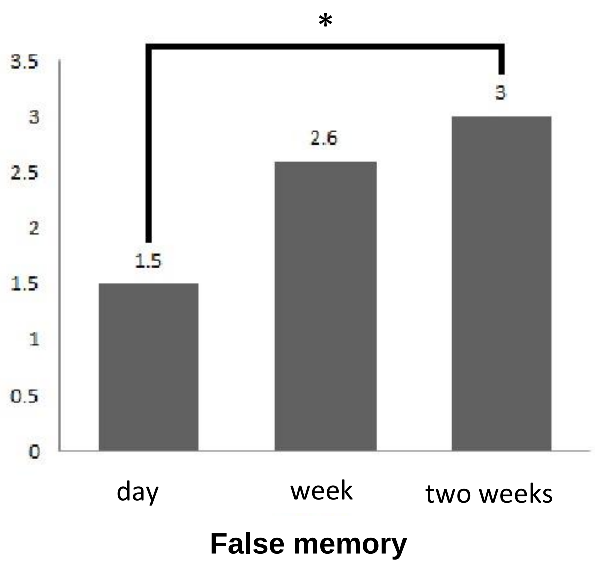


Figure 6.4 – Mean false memory after different time delays.

6.3.3.1 Performed correct

Friedman's test showed that there was a significant difference in the number of correctly recalled different types of actions, $\chi^2(2) = 7.23$, $p<0.05$. Post hoc test was analysis with Wilcoxon tests was conducted with Bonferroni correction applied, resulting in significance level set at $p<0.016$. The Wilcoxon tests showed that there was significantly more communicative actions were correctly recalled as self-performed than meaningful actions ($Z = -2.42$, $p<0.016$). There was no significant difference found between correctly recalled meaningful and meaningless action ($p>0.016$), and meaningless and communicative actions ($p>0.016$), which suggest that the correct recall of those actions was equally challenging.

6.3.3.2 Performed incorrect

It was found that the difference in the number of incorrectly recalled performed actions (where participants state that they had never performed the action but in fact they had) was significant between the performed meaningful and meaningless actions with, $t(29) = 2.18$, $p<0.05$ and meaningful and communicative, $t(29) = -5.52$ $p<0.001$. These results suggest that participants were more likely to not remember having performed meaningful actions compared than meaningless and communicative. There was no significant difference found in incorrect recall of meaningless and communicative actions ($p>0.05$). The corresponding non-parametric analysis was conducted and revealed the same results.

6.3.3.3 Observed correct

To recap, this value represents the actions that are correctly recalled as not having been performed. The results of the paired-samples t-test show that there was a significant difference between the observed communicative and meaningless actions correctly recalled as not having been performed with $t(29) = -3.9$, $p<0.001$ and between the meaningful and the communicative $t(29) = 3.71$, $p<0.001$, where fewer communicative than meaningless and meaningful actions were correctly recalled as not having been performed. This means participants were better at discriminating between the source of meaningless and meaningful actions than communicative actions. The corresponding non-parametric analysis was conducted and revealed the same results.

6.3.3.4 False memories

It was found that the number of false memories increased as the testing time delay increased (see Figure 6.4). However, the results of an independent-samples t-test have found this difference to only be significant between one day and two week testing delays, $t(18) = -2.67$. The difference in the recall of false memories has not been found to be significant between one day and one week ($p>0.05$) and one week and two weeks ($p>0.05$) testing delay. The corresponding non-parametric analysis was conducted and revealed the same results.

6.4 Discussion

6.4.1 Summary of results

The experiment aimed to investigate OIs formed following observation of different types of actions (meaningful, meaningless and communicative actions) after different time delays (one day, one week and two weeks). OI is a term introduced by Linder et al. (2010) where observed actions are misattributed as performed who also suggested that mirror neurone activity could stand behind any OI effect. It was hypothesised that observation of communicative and meaningful actions would result in significantly more OIs than observation of meaningless actions. The hypothesis was based on research on mirror neurone activation that shows intensified mirror neurone activity during action observation of communicative gestures and meaningful actions (e.g. Husain et al., 2012; Iacoboni, 2008; Montgomery et al., 2007).

The results of the current study have found OIs to be present after observation of all three types of actions, demonstrating that it is possible to form memories of self-performance through observation of actions of others. The highest number of OIs formed was recorded for communicative actions, which was in line with our hypothesis. Observation of meaningful actions yielded a similar number of OIs as communicative actions (no significant difference between OI formation for meaningful compared to communicative). The lowest number of OIs was recorded after observation of meaningless actions, which again supports the initial hypothesis with a significant difference found between OIs formed for meaningless actions compared to communicative.

It must be noted that the mean numbers of OIs for all action types were relatively low, with a number of participants performing at floor in some conditions which will be discussed in more detail later in this section.

6.4.2 OIs at different time delays

Furthermore, the effect of time delay between the observation and performance of actions (phase 1) and the source memory test was also investigated. The number of OIs formed was compared between three different time delays (one day, one week and two weeks) and it was found that the highest number of OIs was formed after a two week time delay for communicative and meaningful actions. The formation of OIs after observation of meaningless actions was not affected by testing time delay. This is supported by previous research on memory errors which has demonstrated that memory deteriorates with time (e.g. Porter et al., 2010). For example, Underwood and Pezdek (1998) showed that participants recall significantly more 'false' stimuli after one month testing delay than when they are tested immediately.

6.4.3 Results for other measurements

The correct recall of actions that were performed in the experiment and correctly attributed to its source was also investigated. The results revealed that the highest number of correctly attributed actions to its source was after executing communicative actions. This would imply that communicative actions are the easiest to remember but interestingly communicative actions also formed the highest number of OIs.

The analysis of observed actions correctly recalled as observed was the highest for meaningless actions, followed by meaningful and the lowest for communicative actions. This is because the observation of communicative actions resulted in the highest OI formation, contrary to meaningless and meaningful actions. These results imply that memories for communicative actions are the most accurate when recalling the actions that have been performed, however, the source attribution accuracy declines when one is recalling the source of observed communicative actions.

The results also showed that participants formed 'real' false memories, which means that they misremembered actions that were neither performed nor observed.

6.4.4 Relation to other findings

We propose that the OI effect in the present study is a result of source-monitoring errors, where observed actions are misattributed as self-performed. The source-monitoring error in this instance is hypothesised to occur because the observed and performed actions share the same characteristics, and the observation of movement during execution of action may cause similar neural activity. As a result, shared motor activation between the observed and performed actions causes confusion between the sources and the observed actions are misremembered as self-performed. The OI effect was found to be present after observing all three types of actions, but it was found that significantly more communicative than meaningless actions were misattributed as self-performed. Participants formed more OIs for communicative actions than meaningful; however, this difference was not found to be significant. It is important to note that the mean number of OIs was generally very low and participants were performing at floor level. Improving the OI paradigm so that it yields higher means of OI misattributions could provide a stronger support for the hypothesis and possibly results with significantly more OI formed for communicative than meaningful actions. These results support the hypothesis that communicative and meaningful actions may trigger mirror neurone activity which leads to confusion between the sources of memory.

Previous research shows that communicative emblems elicit mirror neurone activity to a greater extent than meaningless actions. For example Husain et al. (2012) found that observation of communicative emblems but not meaningless actions activated areas related to processing of auditory information in deaf participants, and brain areas associated with mirror neurone activity such as the premotor cortex and the inferior parietal lobule in hearing participants. Husain et al. (2012) proposes that since communicative emblems are comparable to spoken words, deaf participants process it as linguistic information, and hearing participants categorise the communicative emblems in terms of pictorial descriptions.

Similar results were found by Andric et al. (2013) who found that observation of speech articulation, grasping and communicative emblems activated the same brain areas. The overlapping activation was present in the lateral temporal, inferior frontal, parietal and premotor areas when the speech, emblems and grasping were observed. Furthermore, communicative emblems but neither grasping nor speech activated areas thought to be associated with processing the intentions of others (Andric et al., 2013). Heightened correct recall of communicative actions as performed could suggest a generally stronger memory for these actions than for meaningful or meaningless in this experiment.

Research shows that observation of meaningless actions triggers little corticospinal activity in comparison to observation of goal-directed actions and communicative emblems (Donne et al., 2011). Similarly Newman-Norlund et al. (2009) found that observation of meaningful and meaningless object-directed actions elicits different mirror neurone responses, showing different localisation of activation in bilateral sub-marginal gyrus.

The results of this study show that it is possible to form memories of self-performance by observing other people performing actions. This was first shown by Lindner et al. (2010) who used actions that are considered meaningful (although no full list of actions used was provided in that paper). The study of this chapter extended this and looked at the formation of OIs for different types of actions. If the hypothesis that mirror neurone involvement can stand behind and OI effect then it is proposed that there will be less source-confusion for meaningless actions (low or no mirror neurone activity, e.g. Donne et al., 2011; Husain et al., 2012) and greater source-confusion for meaningful (high mirror neurone activity, e.g. Buccino et al., 2004; Gallese et al., 1996) and communicative actions (highest mirror neurone activity, e.g. Husain et al., 2012; Andric et al., 2013) resulting in more OIs for the latter two than the former. The highest number of OIs made was for communicative actions which were significantly different from the number of OIs made for meaningless actions. The

OI effect is strongest for communicative actions and after longer time delays (two weeks).

To continue the study it is necessary to encourage higher number of OIs to be formed as numbers were low overall. This could be done by making the stimuli harder, for example by adding more which will tax the memory system more, or creating more interference between the initial phase and the second phase (questionnaire). This could simply be done by extending the time delay even further to longer than two weeks or even months (it was clear from these results that more OIs were made at the longer time delay). Another method to encourage larger number of OIs would be to look at the inflations in a group of participants more prone to forming source-confusion errors (for example the elderly, see Chapter 8). This is also important as one of the potential applications of the OI effect is in the elderly who see other people performing actions (e.g. taking medication) leading them to think that the actions were their own (e.g. they themselves have taken their medication which is false) (Lindner et al., (2010)). This has further implications for sufferers of memory disorders in the elderly such as Alzheimer's disease (AD) and source confusions in this cohort need further investigation.

It must also be noted that objects were used for both the meaningful and meaningless actions and no objects were used for the communicative emblems as these are gestural. Interestingly, previous research on monkeys show that continuous observation of an experimenter executing actions involving tools leads to formation of special tool-responding mirror neurones (Ferrari et al., 2005). The authors suggest that such prolonged association of object and action can result in stronger mirroring activity and enable action understanding (Ferrari et al., 2005).

6.5 Summary

This chapter discussed previous studies on the OI effect, which demonstrated that observation of other peoples' actions can result in memories of self-performance. The results have demonstrated that correct attribution of the source of a memory can be challenging for participants. Based on the research on imitation and mirror neurones, it was hypothesised that observation of communicative and meaningful actions would result in higher rates of OIs. This is because these types of action show enhanced mirror neurone activity (e.g. Husain et al., 2012; Andric et al., 2010) and an imitation advantage (e.g. Rumiati and Tessari, 2002; Carmo and Rumiati, 2009) compared to meaningless actions. The present study found that there were significantly more OIs formed after observing communicative actions compared to after observing meaningless actions. The highest number of OIs was recorded after a two week time delay rather than after one day or one week, suggesting that source memory accuracy decreases over time. This is not surprising and is in line with previous research on the effect of time on memory errors (e.g. Porter et al., 2010).

6.5.1 Highlights

- Research on OI demonstrates it is possible to form SMEs of self-performance after observing actions being performed by somebody else.
- Studies show higher misattribution rates for observed actions than read action statements as self-performed. This effect persists even in the presence of source monitoring instruction and specific OI warnings (Lindner et al., 2010).
- Research on mirror neurones shows that observation of actions elicits the same or similar brain activity as when the action is actually performed. This activity has been found to be stronger for actions that are communicative or goal-directed than meaningless actions (e.g. Newman-Norlund, et al., 2009; Husain et al., 2012).
- This study hypothesised a higher rate of OI will be formed following observation of communicative and meaningful than meaningless actions.
- This research replicates the finding that memories of self-performance can be formed after observing actions (e.g. Lindner et al., 2010, Schain e al., 2012).
- The experiment found that the highest number of OIs is for communicative actions followed by meaningful followed by meaningless with significance between the number of OIs formed for communicative and meaningless.
- The highest number of OIs was formed after two week time delay for meaningful and communicative actions.

- Significantly higher number of misattributions for communicative than meaningless actions suggests possible mirror neurone involvement.
- The highest number of correct source attributions was recorded for communicative actions. Interestingly, the highest number of misattributions of actions performed by others as self-performed was also for communicative actions.
- OI has possible implications for elderly, who has been shown to exhibit problems with correct source-monitoring (this is discussed in Chapter 8).
- Future research should aim to create OI paradigm that would yield higher mean number of OI than in the current study.
- Possibly testing this paradigm on elderly sample would result in more OI formation as the elderly has been shown to exhibit problems with accurate source monitoring.

Some of this information can be found in Mitrenga et al. (in prep) - The observation inflation effect – memory for different types of actions'

Chapter 7

Self-action inflation - misattribution of self-performed actions as observed

7.1 Introduction

7.1.1 Background

In Chapter 6, the OI effect was investigated by looking at the difference in misattributions of observed actions as self-performed between different types of actions (meaningful, meaningless and communicative) and comparing their recall over different time delays. Of particular interest was the difference in OIs formed between three types of actions, as research on mirror neurones (e.g. Montgomery et al. 2007; Andric et al. 2013; Ferrari et al. 2003; Wriessnegger et al. 2013) and imitation (e.g. Rumiati and Tessari 2002; Tessari et al., 2006; Carmo and Rumiati, 2009) has shown that actions are processed differently depending on their type. If mirror neurones are involved in the formation of OIs as suggested by previous researchers (Lindner et al., 2010), it can be hypothesised that a different number of OIs between these different types of actions would be seen. If mirror neurone activity is greater during observation of actions that are communicative or meaningful as compared to meaningless, it would be plausible to assume that the similarity in activation between observation and actual performance in the actions with high mirror neurone activity could lead to source attribution failures and hence the finding that participants recall the observed actions as self-performed.

This was tested in Experiment 1 (Chapter 6) and the hypothesis was supported. A significantly higher number of OIs were made between communicative actions and meaningless actions, and although more communicative than meaningful actions resulted in OIs, this was not found to be significant. Meaningful and meaningless actions were equally likely to result in OIs.

This chapter further investigates the mirror neurone hypothesis by studying the potential misattributions of self-performed actions as actions that are performed by somebody else. This will be referred to as self-action inflation (SAI).

7.1.2 Misattribution of self-generated actions to others – evidence from schizophrenia patients

Some existing research has studied a similar concept of attribution of self-generated actions to other people or entities, particularly in schizophrenic patients. Misattribution of self-performed actions to others is a common occurrence in schizophrenic patients, a manifestation of so called positive symptoms, specifically hallucinations (Jeannerod and Pacherie, 2004). Patients demonstrate an inability to recognise their own actions as self-generated and attribute them to other people or 'entities' (e.g. alien forces) instead of themselves. This type of source attribution error is called 'under-attribution' in the context of schizophrenia. This is thought to be a product of action monitoring failure, where the patient is unaware of producing the movements.

This effect has been studied experimentally in a number of studies. For example, Daprati et al. (1997) tested misattributions of self-performed actions in 30 healthy participants and 30 schizophrenic patients. In their study, participants of both groups were required to perform hand movements and monitor a hand movement on a nearby screen, which was performing either compatible or incompatible actions to the ones that participant was executing. An example of the movement would be extending index finger or opening hand wide. After each movement was executed/observed, participants were asked to judge whether the observed movement was performed by themselves or somebody else (hand on the screen). The results revealed that healthy control subjects successfully recognised their own actions if the observed actions were incompatible with the ones they were performing. However, when the observed actions were compatible with the one they were executing, they misattributed 30% of observed actions as having been performed by somebody else. Schizophrenic patients misattributed 80% of self-generated actions as performed by somebody else. Frith (2005) suggested that this type of misattribution is a result of failure in 'self-monitoring', which is an inability to monitor one’s own intentions to execute the action. One does not anticipate performing the action and the movement is then surprising to the patient. Hence, it is likely to be interpreted as having been performed by somebody else.

Treur and Umair (2011) proposed a cognitive model for misattributions of self-performed actions to others. According to Treur and Umair (2011), the misattribution happens through 'inverse monitoring' which is mapping of one’s own action repertoire onto another person, resulting in a mental image of them performing the action. This 'inverse monitoring' requires applying mental rotation of changing the perspective from self-performed (first person perspective) to being performed by somebody else (third person perspective) (Treur and Umair, 2011).

7.1.3 Other evidence of attributing self-performed actions to others

Furthermore, some evidence on a SAI effect comes from Manzi and Nigro's (2008) study, where recollective experience of correct source attribution was the primary aim of their study. Manzi and Nigro (2008) not only found that participants misattributed observed actions as self-performed but also the actions they performed themselves as performed by somebody else. Additionally, it was found that participants misattributed self-generated actions as observed significantly more than they misattributed observed actions as self-performed.

Manzi and Nigro (2008) attributed this effect to errors in source monitoring and mirror neurone activity. According to Manzi and Nigro (2008), observed actions provide more visual discriminatory features (the image of the person performing the action, and features such as their clothing as an example) than self-performed actions that only provide motor parameters as a basis for source differentiation. But on the other hand, Manzi and Nigro (2008) suggest that the inflated number of misattributions for self-performed actions could be caused by so called 'it-had-to-be-you' effect, where weak memory traces are misattributed to others because of lack of sufficient detail to be considered as self-performed (Manzi and Nigro, 2008).

7.1.4 Aim of the study

The aim of this study is to further investigate the hypothesis that mirror neurones are involved in SMEs. If the mirror neurone hypothesis holds, then surely mirror neurone activation should be present whatever the mode of retrieval, either asking what the participants observed or asking what the participants performed. Therefore, instead of looking at source misattributions for the *observed* actions, as was done in the experiment of Chapter 6, the source misattributions of *performed* actions will now be investigated. In the OI experiment of Chapter 6 participants were asked, after firstly observing and executing actions, to indicate which actions they remember *performing* themselves and a significant number OIs formed for communicative as compared to meaningless were found. Observation of communicative actions resulted in more OIs than meaningful actions, however, this difference in OIs has not found to be statistically significant. Meaningful and meaningless actions were equally likely to result in OIs. In the present study participants will be asked which actions they remember *observing* (again after observation and execution of actions) in order to study the possible misattributions of performed actions as observed. If mirror neurone activity is involved in the misattributions of observed actions as performed actions (OI) because it activates overlapping brain regions responsible for motor control and motor memory, the same SME should be observed in reverse in the present study. As stated above, this will be referred to as a 'self-action inflation' (SAI) effect, where self-performed actions are erroneously attributed as observed, i.e. actions incorrectly recalled as being performed by another person.

7.1.5 Hypothesis

If there is mirror neurone involvement, the hypothesis is that the same pattern of results should be seen as that was found in the OI condition which is more source misattributions formed for communicative and meaningful actions than meaningless actions.

7.2 Methods

7.2.1 Participants

Thirty participants (mean age = 27.92) which consisted of thirteen males (mean age = 27.78, SD = 5.54) and seventeen females (mean age = 27.92, SD = 11.28), recruited from the University of Bradford took part in the experiment. As with the OI experiment of Chapter 6, the inclusion criteria for participation were no history of autism and no uncorrectable visual impairments. The participants were different from those that had participated in the OI experiment. Ethical approval was obtained from Humanities, Social and Health Sciences Research Ethics Committee at University of Bradford.

7.2.2 Design

A mixed experimental design was used. The within-subject factor was different action type (meaningful, meaningless and communicative). Participants in this study were asked to observe a presentation consisting of videos of three different types of actions and to perform some actions themselves (the same stimuli as used in Chapter 6). The between-subject variable was a different time delay for assessing SAIs (day, week or two weeks).

7.2.3 Materials

The same videos and PowerPoint presentation used for the OI experiment were used. The only difference was the wording of the memory questionnaire in the test phase of the experiment. This time, in order to test SAIs the items in the questionnaire consisted of sentences written in the impersonal form for example, ‘a person opened a bottle’ and the questions asked whether the participant remembered *observing* the actions instead of *performing* them (Chapter 6). The sentences contained 30 actions that participants performed and 30 actions that they had observed in the PowerPoint presentation (See Appendix 2 for the full list of actions used in the experiment). Additionally, as for Experiment 1 (Chapter 6), 20 actions that were neither observed nor performed were added to the questionnaire in order to test true false memories.

As in the OI experiment of Chapter 6, the R-K-G paradigm was included in the source memory questionnaire in order to test recollective experience of the formed misattributions. The recollection of SAIs will be discussed in Chapter 10.

7.2.4 Procedure

The same procedure as for the OI experiment of Chapter 6 was employed.

7.3 Results

The aim of the study was to investigate the formation of SAIs as a result of action execution for different types of actions. SAIs are where participants state that they observed an action, when they had actually performed that action. Figure 7.1 shows the number of SAIs formed.

The 'Remember' and 'Know' responses were summed to create the SAI variable. The 'Guess' recollection is discussed in Chapter 10.

7.3.1 Self-action inflations

The results show that the highest number of SAIs was formed after execution of meaningless and communicative actions and fewest for meaningful actions (See Figure 7.1).

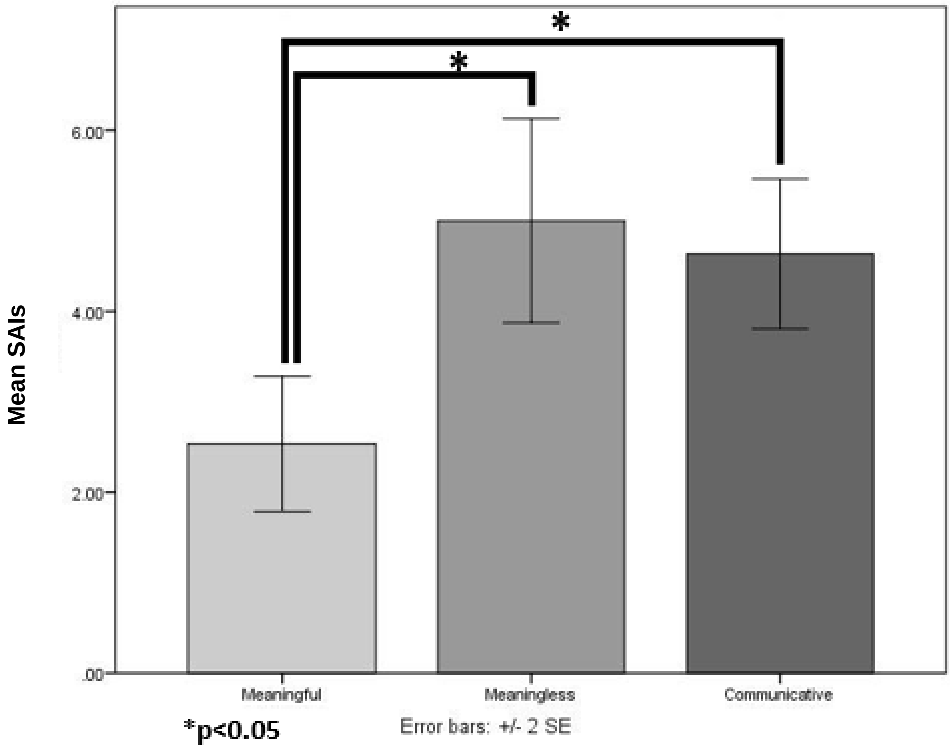


Figure 7.1 – Mean and standard errors for SAIs for meaningful, meaningless and communicative action types.

The assumption of normality has not been met for the sample conditions Standard parametrical tests were carried out alongside non-parametric test. For this experiment both analyses showed the same results. The parametric analysis is reported.

The data was further analysed with 3x3 mixed ANOVA, where the within-subject factor was the action type (meaningful vs. meaningless vs. communicative) and the between-subject factor was the time delay in testing (day vs. week vs. two weeks). The analysis revealed a significant main effect of action type ($F(2, 54) = 31.1$, $p<0.001$).

Pairwise-comparisons show significant differences in the number of SAIs formed between the meaningful and meaningless action ($p<0.05$) and between the meaningful and communicative action types ($p<0.05$). No significant difference in the formation of SAIs was found between meaningless and communicative actions ($p>0.05$). This shows that the participants formed the highest number of SAI errors for meaningless actions and communicative actions and are *less* likely to form SAIs for meaningful actions.

7.3.2 Self-action inflations over different time delays

Participants carried out the SAI memory test after one day, one week and two weeks. The results of this can be seen in Figure 7.2.

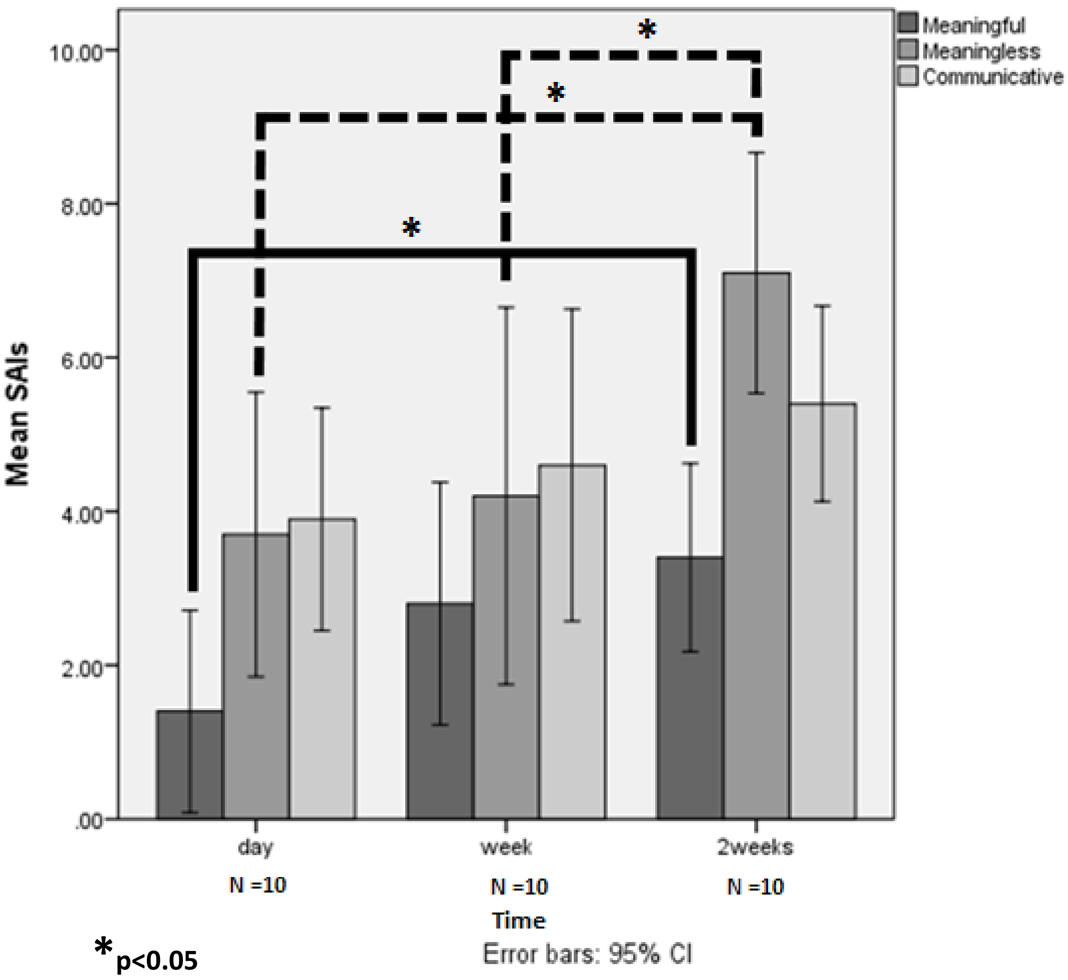


Figure 7.2 – shows that the mean number of SAIs increases with time in all action type conditions (mean SAIs for all actions combined for one day = 9, one week = 11.6 and two weeks = 15.9).

7.3.2.1. Main effects of testing delay

The results revealed a marginally significant main effect of testing delay, $F(2, 27) = 3.1$, $p=0.06$. The pairwise-comparisons reveal that there is only a marginally significant difference between the number of SAIs overall (regardless of action type) found between one day and two weeks, ($p=0.06$).

7.3.2.2 Action type and testing delay

There was a significant interaction found between the action type and the length of time delay in testing participants, $F(4, 54) = 2.75$, $p<0.05$ showing that different types of actions resulted in different patterns of SAIs at different time delays.

Independent-samples t-tests found a significant difference in the number of SAIs formed for meaningful actions between two weeks and one day test delay, $t(18) = -2.52$, $p<0.05$. This means that participants formed more SAIs after performing meaningful actions after a two week delay in testing than after one day. It was also revealed that participants formed more SAIs for meaningless actions after a two week testing delay compared to a one week testing delay, $t(18) = -3.18$, $p=0.05$, and compared to a one day testing delay, $t(18) = -2.26$, $p<0.05$. None of the other time delays for meaningful actions and meaningless actions reached significance.

There was no significant difference found between the SAIs formed for communicative actions at any of the different time delays ($p>0.05$).

7.3.3 Other measurements

Although the primary aim was to investigate SAIs, the other measurements recorded are important to report. The other results were the numbers of actions that were (i) *"observed correct*" which is where participants had observed the action in the PowerPoint slides in the study phase of the experiment AND subsequently correctly recognised that they had observed the action on the questionnaire (ii) *"observed incorrect"* – where participants indicate on the questionnaire that they had never observed the action (ticking 'no') but in fact they had during the PowerPoint stage of the study phase of the experiment (iii) *"performed correct"* – where participants remember correctly that they have not observed the action e.g. in response to the phrase 'A person shook a bottle' on the questionnaire, which they had performed in the study phase, participants tick 'no', and they indeed had only performed the action. The final measurement is (iv) *"false memories"* where participants remember observing an action that they neither performed nor observed. These results are presented in Table 7.1.

7.3.3.1 Observed correct

Analysis with paired sample t-tests showed that significantly more meaningful actions were recalled correctly than meaningless ($t(29) = -4.65$ $p<0.001$) and communicative ($t(29) = 2.89$, $p<0.05$). More communicative actions were correctly recalled than meaningless actions ($t(29) = 2.15$, $p<0.05$). Interestingly in the Experiment 1, communicative actions were more likely to be correctly recalled than meaningful actions. Also more communicative actions were correctly recalled than meaningless, however this was not found to be statistically significant ($p>0.05$). The same as in the current study, more meaningful actions than meaningless actions were correctly recalled. This is interesting as the same actions were used in this experiment as in the OI experiment, but did not result in a same pattern of correct source attributions.

Table 7.1 – Mean SAIs and correct recall for all action type conditions after different time delays.

	Meaningful				Meaningless				Communicative			
	Day	**Week**	**2 Weeks**	**Total**	**Day**	**Week**	**2 Weeks**	**Total**	**Day**	**Week**	**2 Weeks**	**Total**
Observed correct	6.4	4.2	4.2	**4.93**	8.4	7.1	5.7	**7.06**	6.6	5.9	5.9	**6.13**
Observed incorrect	3.6	5.8	5.8	**5.07**	1.6	2.9	4.3	**2.93**	3.4	4.1	4.1	**3.87**
Performed correct	8.6	7.2	6.6	**7.47**	6.3	5.8	2.9	**5**	6.1	5.4	4.6	**5.37**

7.3.3.2 Performed correct

Paired sample t-tests revealed that there was a significant difference between the unperformed meaningful and meaningless actions correctly recalled as unperformed ($t(29) = 6.69$, $p<0.001$) and meaningful and communicative actions ($t(29) = -8.45$, $p<0.001$), where more meaningful than meaningless and communicative actions were correctly recalled as unperformed. There was no significant difference ($p>0.05$) in the number of meaningless and communicative actions, which suggests that participants found them equally challenging to attribute as unperformed.

7.3.3.3 Observed incorrect

There was a significant difference in the number of incorrectly recalled observed actions as unobserved between the observed meaningful actions and meaningless ($t(29) = 4.7$, $p<0.001$), meaningful and communicative actions ($t(29) = -2.98$, $p<0.05$) and meaningless and communicative ($t(29) = -2.15$, $p<0.05$).

These results suggest that participants were more likely to incorrectly recall observed meaningful actions as unobserved, rather than meaningless and communicative.

7.3.3.4 False memory

The number of false memories increased as the testing time delay increased (day mean = 4.1, week mean = 5.1, two weeks mean = 6.9). However, significance was only found between a one day and two week testing delay, $t(18) = -2.67$, $p<0.05$.

7.3.4 Comparison of OIs (Experiment 1) and SAIs (current study)

The results of Experiment 1 (OI, Chapter 6) showed a mean score of all OIs to be 3.93 (SD = 3.23) and the results of the current experiment (SAI, Chapter 7) showed a mean score of all SAIs to be 12.71 (SD = 6.71). Statistical analysis with independent-samples t-test revealed that significantly more SAIs were made in the current study than OIs in Experiment 1 (Chapter 6), $t(61) = -6.45$, $p<0.001$.

7.4 Discussion

7.4.1 Aim of the study

The purpose of this experiment was to investigate SAIs for different types of actions. As far as I am aware, the SAI effect has only been researched in the schizophrenia literature. SAIs occur when the source of a self-performed action is misattributed as being observed in other person. Based on the hypothesis of Lindner et al., (2010) that mirror neurones may stand behind an OI effect, it was hypothesised that if this is true, SAIs should also be formed with a same pattern of results. Again if motor areas are both activated when both performing and observing an action, and there is mirror neurone activity, then not only OIs but also SAIs should be formed with different patterns for different action types.

7.4.2 Summary of results

Firstly and importantly, the results of the current experiment have shown that execution of actions can result in SAIs, where participants remember observing a person performing an action, when it was in fact themselves who had performed that action. It was found that significantly more meaningless than meaningful actions ($p<0.05$) resulted in SAIs formation, and significantly more communicative actions than meaningful actions resulted in SAIs ($p<0.05$). The highest number of SAIs was found after performing meaningless and communicative actions with meaningful actions forming the fewest SAIs. The highest number of SAIs was formed after a two week time delay for all the action types. It was also found that the number of SAIs significantly increased for meaningless actions between one day, a week and a two week testing delays. Also, the number of SAIs formed for meaningful actions significantly increased between one day and two weeks. Interestingly, SAIs formed for communicative actions did not differ significantly between the three time delays. This is not in line with the results of Experiment 1, which showed that significantly more OIs were formed for communicative and meaningful actions after a two week time delay than one week and one day.

It is especially interesting that the highest number of misattributions was observed for meaningless and communicative actions, meaning that participants were more likely to answer that they remember falsely observing meaningless and communicative actions rather than meaningful. It remains unclear if the source memory is particularly bad for meaningless and communicative actions or if the source memory trace is simply very good for the meaningful condition. However, unlike the OI experiment in Chapter 6, participants were better at remembering the meaningful actions overall (as shown by the performed and observed correct score). Although this is a potential explanation of the results here, it is an interesting finding in and of itself as the same actions were used in both experiments just the wording of the questionnaire changed between the experiments. The wording changed from, for example, *'I shook the bottle'* in the OI experiment of Chapter 6 to *'A person shook a bottle'* in this experiment. Note also that the number of SAIs made were much higher than the number of OIs made in the experiment of Chapter 6 (on average, participants made significantly more SAIs), which is in line with the results of Manzi and Nigro (2008). This also, unfortunately for the original mirror neurone hypothesis, makes it clear that the wording of the questionnaire is having a priming effect that may be masking potentially more subtle effects, for example mirror neurone activity. This also calls into question the results of the OI experiment (Chapter 6) as again the questionnaire is potentially masking other results. Given that total SAI numbers were higher than total OI numbers (and that OI numbers were very low with participants performing at ceiling), leads to the suggestion that this paradigm may be better for studying source inflations.

Although similar results to this experiment were found for the OI experiment of Chapter 6, in that communicative actions formed a high number of OIs, one strong difference is the increased number of SAIs formed for the meaningless action type. At this stage of the research it is unclear as to why this result was obtained and is potentially problematic for the idea of mirror neurones standing behind the effect (simply because the effect should be stronger for meaningful and communicative as seen in the OI experiment). However as stated above, the wording of the questionnaire is clearly biasing the results so any effect of mirror neurone activity is weaker than the bias. It is therefore difficult to make any strong conclusions regarding mirror neurone activity here.

Mirror neurone studies show that in order for mirror neurones to be activated, the action needs to be goal-directed and the observer needs to understand that goal (Gallese et al., 1996). For example, mirror neurones are not activated when an object or a person is visible alone nor when the action is mimed. It was found that mirror neurones are active when the monkey observes the experimenter grasping for a peanut, but not when the experimenter mimics grasping for a peanut or when the monkey sees the peanut alone (Gallese et al., 1996). A similar effect has been found by Ferrari et al. (2003) where mirror neurones were active when a monkey observed the experimenter drinking juice from the syringe but not when the syringe was presented alone nor when the experimenter mimed the gesture of drinking (Ferrari et al., 2003). Selective mirror neurone activation for meaningful transitive (requiring object manipulation) actions has also been found in humans. For example Enticott et al. (2010) found that mirror neurone activation was only present when participants observed meaningful hand actions and not meaningless actions nor a static hand.

As previously discussed, meaningless actions are unfamiliar and novel to participants (Rumiati and Tessari, 2002) and execution or observation of them may be 'strange' to participants, which could result in a more detailed memory of them than of meaningful actions which do not share the distinctiveness of meaningless actions. They are the actions encountered in everyday life, being frequently observed and performed. Thus, when participants were presented with the statements of meaningless actions in the memory test, and asked whether they had observed someone performing the 'strange' action, they made a high number of SAIs. It seems likely that participants remember performing and observing a number of meaningless actions as a hierarchical entity but the strange nature of the individual features make them hard to discriminate. They seem to have less of a problem discriminating when asked of what they performed themselves in Experiment 1 than in this experiment, so they are using a different recall method.

Regarding the high misattribution of self-performed communicative actions as performed by somebody else, the result of this study is similar to the findings of

Experiment 1 (Chapter 6), where the highest number of OI errors was made following observation of communicative actions. This supports the initial hypothesis of possible mirror neurone involvement, which stated that both execution and observation of actions elicit similar brain activity, which in result could lead to mistakes in memory source attribution. As previous research on mirror neurones and imitation indicates that communicative actions tend to elicit greater mirror neurone activation and have imitation advantage over meaningless or even meaningful actions, we can speculate that in both Experiment 1 (Chapter 6) and the current study, the observation of communicative actions could have resulted in higher mirror neurone activation which made it more difficult for participants to find the correct source of their memory for the communicative actions. However, the clear bias of the questionnaire makes this more speculative.

7.4.3 Summary and conclusion

The results of the experiment show that the observation and performance of actions can lead to confusing the source of these actions. Specifically, self-performed actions can be remembered as observed actions, the effect to which we refer as self-action inflation with the highest number for meaningless and communicative actions. Furthermore, people make higher numbers of SAIs as compared to OIs which fits firmly in the mirror neurones hypothesis. This study revealed a strong bias effect from the questionnaire, therefore to avoid this in the next experiment we intended to control for this by creating a questionnaire that avoids these biases.

7.5 Highlights

- Observation of actions results in memories of actually performing those actions (Chapter 6).
- Mirror neurones have been proposed to be behind OI effect.
- Observation and execution of action share the same mirror neurone activity which could make the source memory differentiation more difficult.
- It was hypothesised that if there is mirror neurone involvement the same pattern of results should be seen as that was found in the OI experiment

(Chapter 6). This is a higher level of misattributions formed for communicative and meaningful actions than meaningless actions.

- The reverse of the OI effect, ‘self-action inflation’ (SAI) was demonstrated in this experiment.
- SAI is an effect in which one falsely misattributes self-performed actions as performed by somebody else.
- Significantly more communicative and meaningless actions than meaningful actions resulted in SAIs.
- Unfamiliarity and lack of motor memory are potential explanations of the inflation for meaningless type of actions.
- Clear bias coming from wording of the questionnaire.
- On average, significantly more SAI errors were made in this experiment than OI errors in experiment 1 (Chapter 6).

Some of this information can be found in Mitrenga et al. (in prep) – ‘Self-action inflation - misattribution of self-performed actions as observed’.

Chapter 8

Observation inflation in the cohort of elderly participants

8.1 Introduction

8.1.1 Age and source monitoring

Source monitoring in the elderly has been a subject of a great deal of memory research. The past research shows a decline in source monitoring accuracy in the elderly. For example, the elderly tend to recall the ***contents*** of memories better than the ***source*** of a given memory. This has been demonstrated in a study where young (mean age = 23.47) and elderly (mean age = 70.30) participants were asked to recall, recognize and identify the source of a sentence (e.g. who said a given word) (Ruiz-Gallego-Largo et al., 2012). The participants had a conversation with the researcher in which both the researcher and the participants were required to exchange statements describing themselves. A source memory test showed greater impairments in identifying the source of the listened to description in older rather than younger adults (Ruiz-Gallego-Largo et al., 2012). Furthermore, on average, younger participants recalled more descriptive statements than older participants, and they recalled more statements about themselves than about the researcher. Younger participants were better at recognising the statements they read about themselves as compared to the older participants (Rui-Gallego-Largo et al., 2012).

In another study on source monitoring accuracy in elderly participants, Mitchell et al. (2002) presented a video portraying a burglary to a group of young and elderly participants. Following this, the participants were asked a set of misleading questions about the depicted burglary. The questions were asked about non-presented details in a way that suggested to participants that they had in fact been present during the video. The participants then took a source memory test, in which they listened to a male voice reading statements out loud describing (i) the actions which were presented in the videos and (ii) the misleading information about the burglary. The participants then had to decide whether or not they had previously seen the information. The responses were recorded on an answer sheet with a seven-point scale which ranged from 'definitely not' to 'definitely yes'. The results showed that elderly participants were more likely than younger adults to recall the misleading information that was suggested to them in the questions as true events that they observed in the video. Additionally, older participants indicated higher confidence levels for the false memories than younger adults.

In another study, Norman and Schacter (1997) presented young (mean age = 19) and elderly (mean age = 68) participants with a list of words and asked them to describe their memories in detail for words that they had recalled with ‘Remember’ judgements. The results showed that older participants made significantly more recollection errors than younger adults. Also, older adults showed more recollection of associative details (e.g. visual details, smell and sound) rather than contextual details (e.g. location, spatial arrangements, setting) about falsely recollected non-presented words and the descriptions of ‘Remembered’ non-presented words were of higher similarity to the observed ones than in younger adults (Norman and Schacter, 1997).

The lower performance on source monitoring tasks in elderly participants may differ depending on which type of source monitoring is studied. Hashtroudi et al. (1990) suggest that older adults show a different pattern of source recall when they are tested on external reality monitoring. External reality monitoring is the ability to discriminate between two external sources of information, for example, being able to discriminate between words one person says from words that another person has said. Internal reality monitoring is the ability to discriminate between internal sources, for example what someone has said themselves from what they had thought. In the study of Hashtroudi et al. (1990), participants were exposed to a list of words coming from different sources. A combination of internal-external, external-external and internal-internal source monitoring tasks was presented to them. For example, in the internal-external condition, participants were required to both say a list of words (internal) and listen to a list of words (read aloud by the researchers). In the test phase, they were asked to identify the correct source of those words, either external or internal. In the within-monitoring task, for example internal-internal monitoring, participants were required to both say a list of words and imagine saying the words themselves.

The results showed a greater deficit in correct source identification when the words that were of the within condition (internal-internal or external-external). No difference was found in correct source attribution between young and older adults when they were identifying the source between the monitoring (internal-external). Hastroudi et al., (1990) suggest that such deficit in correct attribution of source of information is specific (internal or external monitoring) rather than general (reality monitoring).

Similar results were found by Haj et al. (2012), who studied source attributions in tasks involving (i) reality monitoring, (ii) external monitoring and (iii) internal monitoring. The performance was compared between young (mean age = 21.78 years) and elderly participants (mean age = 73.28 years) and AD participants (mean age = 76.11 years). In the reality monitoring task, participants either observed a researcher placing objects in a bag or placed the objects in a bag themselves and subsequently had to recall whether it was them or the researcher who placed the objects in a bag. In the external monitoring task, participants observed the experimenter placing objects in a bag with a hand covered in either a black or white glove. Following this, participants had to remember whether the objects had been placed in a bag by a hand with a black or a white glove. Finally in the internal monitoring task, participants themselves placed the objects in a bag wearing either black or white gloves and had to remember which objects were placed into a bag while wearing either black or white gloved. The results revealed that elderly participants and AD patients made significantly more errors than young participants. Although AD patients made more errors than older participants, this difference was not found to be significant. Additionally, the results revealed that participants had more difficulty in attributing the correct source of their memories in the external and internal source monitoring. This means that they struggled to remember if the objects were placed in a bag with a white or black gloved hand when they observed the researcher and when they placed the items in a bag themselves. This is in line with results of Hashtroudi et al. (1989) who also demonstrated deficit in internal and external monitoring when compared to reality monitoring.

Further research on source monitoring errors in the elderly and AD patients is important as it can have applications for early diagnosis of AD. Koide et al. (2010)

studied the effectiveness in source monitoring as a possible method of early detection of AD. In their study, healthy elderly, individuals with mild cognitive impairment (MCI) and AD patients were required to (i) observe the researcher arranging small drawings of furniture on a piece of paper, (ii) imagine arranging the drawings themselves and (iii) arrange the drawing themselves. Following that they took a source memory test where they specified the source of the memory for the drawing arrangements. The results revealed that both patients with AD and MCI formed significantly more errors than healthy elderly participants, where they misattributed actions of the experimenter as their own, and actions they imagined as actually performed by them. Koide et al. (2010) used the error scores to generate Receiver Operating Characteristics curves which discriminated AD patients from the MCI participants and the healthy elderly subjects. Koide et al. (2010) suggests this method can have applications as an early detection tool for AD.

8.1.2 Age and OIs

As OI is a relatively new concept in the area of SMEs, there is little research on this subject. As far as I am aware, the only study available looking directly at the effect of OI in older age is a recent study by Lindner and Davidson (2014). In their experiment, the researchers investigated whether elderly participants (mean age = 71.93) would be more prone to form OIs when compared to younger participants. The authors conducted a two stage experiment consisting of an experimental stage and a source memory test. In the first stage, which included two phases, participants either (i) read or performed action statements or (ii) observed videos of actions being performed. Along with reading or performing action statements, a picture of an object would appear on the screen for five seconds. Following this, the researcher put the object in front of the participant and instructed them to only look at the object. After this, the instruction to either read the action statement or perform the action, using the presented object appeared on the computer screen. In total, participants performed 15 actions and read 15 action statements. In the second phase of stage one, the participants observed videos of simple actions being performed. The presentation consisted of 60 actions. The actions used in the study were the same as in Lindner's previous studies on the OI effect (Lindner et al., 2010). As stated previously in this thesis, the authors do not discuss the nature of the presented actions, but from their descriptions and examples included in the article, it is assumed that the actions used were meaningful (e.g. ‘Stamp the paper!’, ‘Ring the bell!’) (Lindner and Davidson, 2014). In the second stage of the experiment, participants took a source memory test, where they answered which actions they remember performing.

The results of Lindner and Davidson’s study (2014) showed a strong OI effect in both young and elderly participants. Additionally, Lindner and Davidson (2014) found that older participants were more prone to form OIs as compared to young participants (significant main effect of age on OIs). Lindner and Davidson (2014) propose that the OI effect in the elderly is a consequence of ‘self-other’ confusion when observed actions trigger similar motor response to when the action is actually performed.

8.1.3 Mirror neurons and ageing

Surprisingly, given the extensive research on mirror neurones published since its discovery almost two decades ago (Gallese et al., 1996), not many have published research on mirror neurone activity in the elderly population. However, the existing research on mirror neurones in the elderly points to similar patterns of activation as in the young adults.

For example, Keerativittatayut et al. (2012) showed 20 healthy elderly participants (age between 60 and 70 years old) a video portraying an actor tearing a piece of paper. An analysis with fMRI found that elderly participants showed activation in the inferior parietal lobule, inferior occipital gyrus and supplementary motor area. Keerativittatayut et al. (2012) also found that observation of visual stimuli (video of an action) activated brain areas responsible for visual processing and further increased the activation into the motor areas.

Additional evidence comes from studies investigating the effect of age on corticomotor facilitation as a result of action observation studied with TMS (Leonard and Tremblay, 2007). Leonard and Tremblay (2007) investigated the changes in the motor-evoked potentials (MEPs) in hand muscles during (i) resting; (ii) observation of videos depicting an action; (iii) imagining performing an action and (iv) imitation of the observed action (the same action of cutting material with scissors was used in all conditions). Young (mean age = 24 years) and elderly (mean age = 62 years) participants were studied in all conditions. The results revealed that both action observation and imagination resulted in hand muscle activation similar to when the action is performed. It was found that the observation and imagery of action increased the MEPs by 55% on average when compared to when participants were resting. The activation was similar between young and elderly participants, again suggesting that the shared motor activation is not affected by age (Leonard and Tremblay, 2007).

Similar results were found in an fMRI study on age differences in mirror neurone activation during observation and imagination of action execution (Nedelko et al., 2010). Results revealed neuronal activation in the premotor and parietal cortex during both observation and imagination of actions. Moreover, the activation pattern did not differ between the young and elderly participants. However, Nedelko et al. (2010) found that the neuronal activation was stronger for the elderly participants, which they attribute to possible neuronal decline due to older age and compensation mechanisms coming into play (Nedelko et al., 2010). In order to maintain the same performance as younger participant, elderly participants need to recruit more cortical units to produce motor actions.

8.1.4 Aim and hypothesis

In this experiment, the OI effect in a group of elderly participants will be investigated. Based on the mirror neurone and OI hypothesis of Lindner et al. (2010), it is hypothesised that the matching neuronal activity for observation and performance will result in the formation of SMEs for observed actions. In the first experimental chapter of this thesis (Chapter 6), it was found that participants formed SMEs for performed actions where they misattributed observed actions as self-performed. However, the numbers of OIs made was very small (mean overall numbers for meaningful = 1.12, meaningless = 0.88 and communicative = 1.73). Therefore in order to create a paradigm that tests OIs better, more OIs need to be induced. Given that source memory errors increase with ageing, if a group of elderly participants can provide data on OIs with higher numbers then this may prove to be a better method of testing OIs experimentally. Given that source monitoring errors are seen in AD patients (Haj et al. 2012; Gallo et al., 2007) it is also important to study this effect in healthy ageing.

Similar to the previous experiments, meaningful, meaningless and communicative emblems were used as stimuli and the memory for the source of the actions was tested with the R-K-G paradigm. The time delay between exposure to stimulus and testing was two weeks given that the previous experiments showed this longer testing delay results in formation of the highest number of OIs (see Chapter 6).

As previous research suggested a decline in source monitoring accuracy in the elderly, it is hypothesised that more OIs will be made in this group as compared to younger participants allowing for a better paradigm to study OIs. Given that the majority of previous research (although there is relatively little) shows that mirror neurone activity is similar in the elderly as in the young, it is also hypothesised that this would be most apparent in the communicative and meaningful condition as seen from the results of Experiment 1 Chapter 6).

8.2 Methods

8.2.1 Participants

Sixteen participants took part in the study, 11 females and five males. All participants were members of the University of Bradford, Division of Psychology over-60s cognitively healthy participant pool. They had a mean age of 72.87 years (SD = 5.29). Inclusion criteria included no uncorrectable visual impairment and no history of autism or dementia. Ethical approval was obtained from the Humanities, Social and Health Sciences Research Ethics Committee at University of Bradford.

8.2.2 Design

A within-subject design was used. The independent variables were the types of actions participants observed and performed in the presentation (meaningful, meaningless and communicative). The dependent variable was the number of (i) OIs formed and (ii) correct source attributions.

8.2.3 Materials

The same experimental stimuli as in Experiments 1 (Chapter 6) and 2 (Chapter 7) were used. Participants observed a video presentation of three types of actions being performed and performed actions themselves. The source memory questionnaire used was the same as in Experiment 1 (Chapter 6).

8.2.4 Procedure

The procedure of the experiment was the same as in the Experiments 1(Chapter 6) and 2 (Chapter 7).

After the experiment, participants were given the R-K-G questionnaire in pre-stamped envelopes and with the researcher's address. They were asked to fill in the questionnaire on a date two weeks from the experiment and send back to the researcher. The participants were telephoned by the researcher one day prior to the agreed date who reminded them that the questionnaire was due to be filled in.

8.3 Results

The aim of this study was to investigate OIs in the cohort of elderly participants (over 60 years, mean age 72.87).

8.3.1 OIs after observation of different types of actions in the elderly

Figure 8.1 shows that the highest number of OIs was formed after observing communicative actions. The lowest number of OIs was formed after observing meaningless actions. This pattern of results is the same as in the Experiment 1 of Chapter 6, where observation of communicative actions resulted in the highest number of OIs formed.

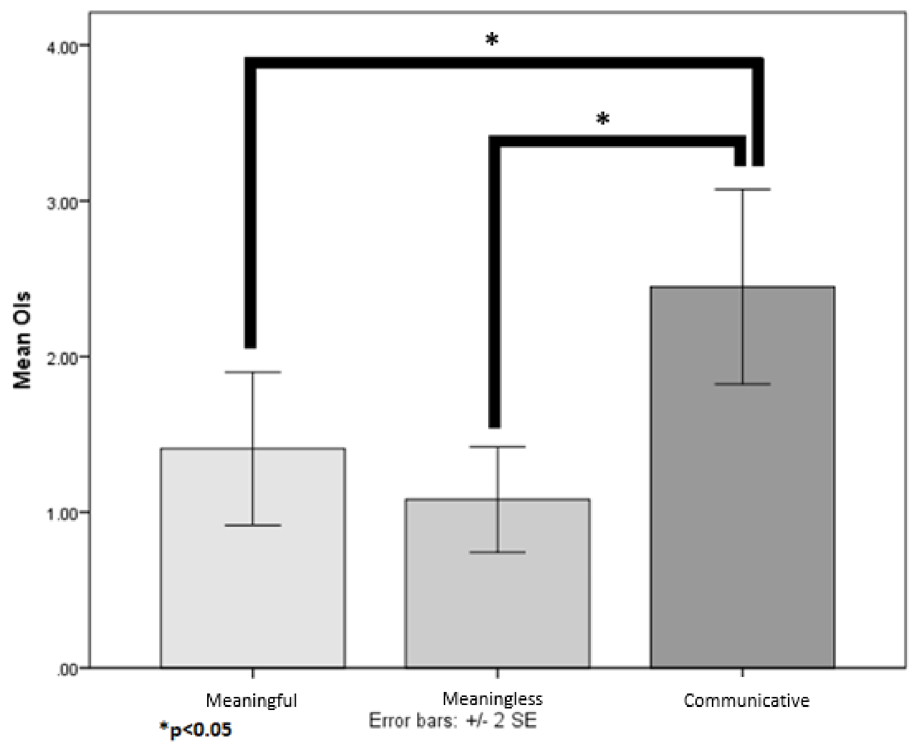


Figure 8.1 – Mean and standard errors of OIs formed after observing meaningful, meaningless and communicative actions in elderly participants.

The assumption of normality has not been met for the sample conditions Standard parametrical tests were carried out alongside non-parametric test. For this experiment both analyses showed the same results. The parametric analysis is reported.

Formal analysis with a repeated-measures ANOVA revealed a significant main effect of action type that participants observed (meaningful vs. meaningless vs. communicative) on the number of OIs formed, $F(2, 30) = 9.15$, $p<0.05$. The OIs are the misattributions of actions observed in the video presentation as self-performed.

Pairwise-comparisons revealed that observation of communicative actions resulted in significantly more OIs than observation of meaningful ($p<0.05$) and meaningless ($p<0.05$) actions. There was no significant difference between the number of OIs formed after observation of meaningful and meaningless actions ($p>0.05$). This pattern of memory errors is the same as the pattern of OIs formed in the study with healthy young adults in Experiment 1 (Chapter 6). However, the number of OIs formed is higher in the cohort of elderly participants. Furthermore, there was no significant difference between the communicative and meaningful actions in Chapter 6 which has reached significance with this cohort, even though there are fewer participant numbers for this study. The differences in the young and elderly data will now be formally investigated.

8.3.2 OIs in the elderly and young adults - a comparison

Figure 8.2 shows the data from the present chapter and data from Experiment 1, Chapter 6; elderly vs. young respectively. It demonstrates that for both groups the same pattern of OIs were seen and that overall the elderly group form more OIs (OI mean = 4.94) than the young (OI mean = 3.73).

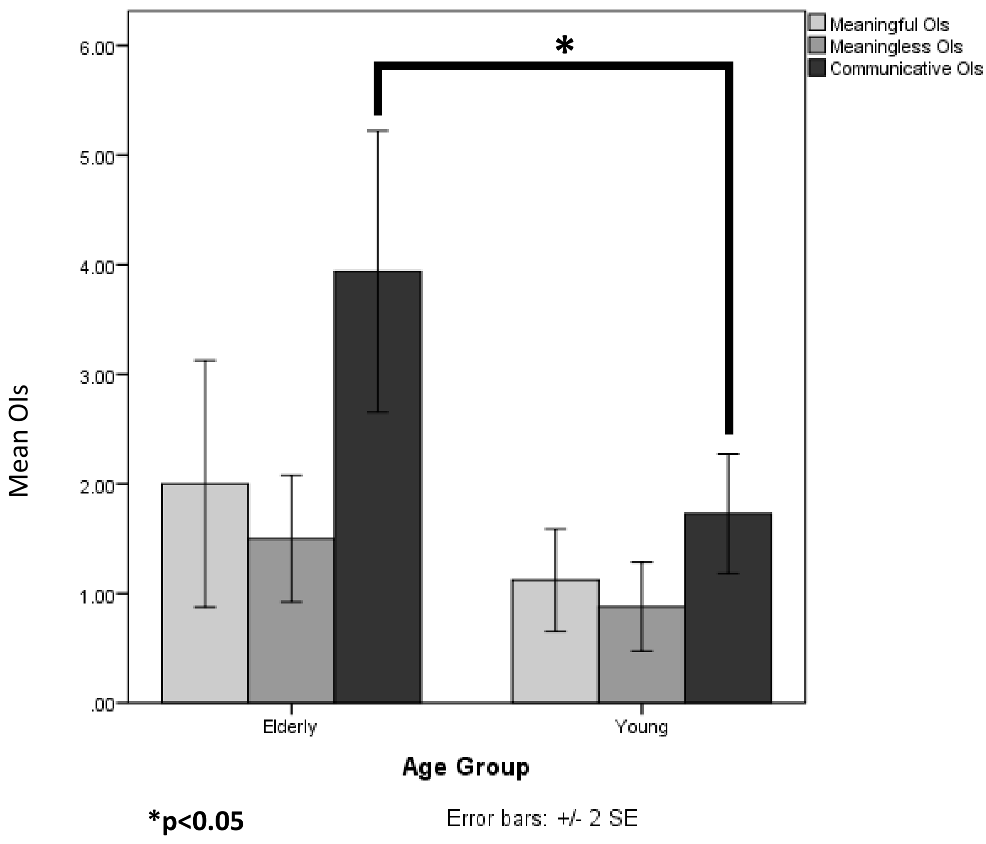


Figure 8.2 – Mean and standard errors of OIs formed after observing meaningful, meaningless and communicative actions in the group of elderly participants and young adults. The results from the young adults are those from the experiment of Chapter 6.

8.3.2.1 Main effects of age group. The OIs in elderly participants (current study) and young participants in Experiment 1 (Chapter 6)

This was analysed with a 2x3 mixed ANOVA, where the age (young vs. elderly) was the between-subjects factor and the action type was the within subject factor (meaningful vs. meaningless vs. communicative). There was a significant main effect of participant group and the number of OIs formed with $F(1, 47) = 10.62$, $p<0.05$, showing that overall, elderly participants formed significantly more OIs than younger adults. The results support other studies (Mitchell et al., 2002; Norman and Schacter, 2007; Haj et al., 2012) which suggest source memory accuracy decreases with age. These results highlight that, investigating this age group may make for a good paradigm to test OIs as larger numbers of OIs are formed.

8.3.2.2. OIs for different types of actions and age

The ANOVA also revealed a significant interaction between the type of action observed and age group on numbers of OIs formed with $F(2, 94) = 4.73$, $p<0.05$. Further exploration of this interaction with independent-samples t-tests showed that there was a significant difference in the number of OIs formed after observing communicative actions between the two age groups ($p<0.05$). Elderly participants formed significantly more OIs after observing communicative actions than younger participants. Although elderly participants formed more OIs (Meaningful mean = 2, Meaningless mean = 1.6) than younger participants (Meaningful mean = 1.12, Meaningless mean = 0.88) after observing meaningful and meaningless actions, this difference was not found to be significant ($p>0.05$).

To summarise, elderly participants formed significantly more OIs than younger adults overall. The formation of OIs for different action types between groups differed significantly only after observing communicative actions, which resulted in more OIs in the elderly than young adult group.

8.3.3 Correct recall of performed actions (elderly participants)

The correct recall is the score for correctly recalled performed actions as self-performed. These results are important as they provide more detail on general source attribution abilities.

Table 8.1 – Mean and standard deviation of correctly recalled performed actions (as performed) in elderly participants.

Action type	Mean	Std. Deviation
Meaningful	3.94	1.69
Meaningless	5.19	2.83
Communicative	6.94	2.69

A repeated measures ANOVA showed that there was a significant difference in the number of actions correctly attributed to their source depending on the type of action, $F(2, 96) = p<0.001$.

Pairwise-comparisons revealed that participants recalled significantly more communicative than meaningful ($p<0.05$) and marginally more meaningless ($p=0.06$) actions to their correct source. This suggests that communicative actions were the easiest to remember as performed. However they still created the highest number of OIs.

A similar pattern of correct recall was observed in the young adult sample in Experiment 1 (Chapter 6) where the highest number of correct source attributions was recorded after performing communicative actions.

8.3.4 False memory

In addition to studying source memory accuracy, 'real' false memories were also studied in the experiment. Additional sentences that described actions that were neither performed nor observed in the experiment were included in the source memory questionnaire. The false sentences in the questionnaire were the same for young and elderly participants.

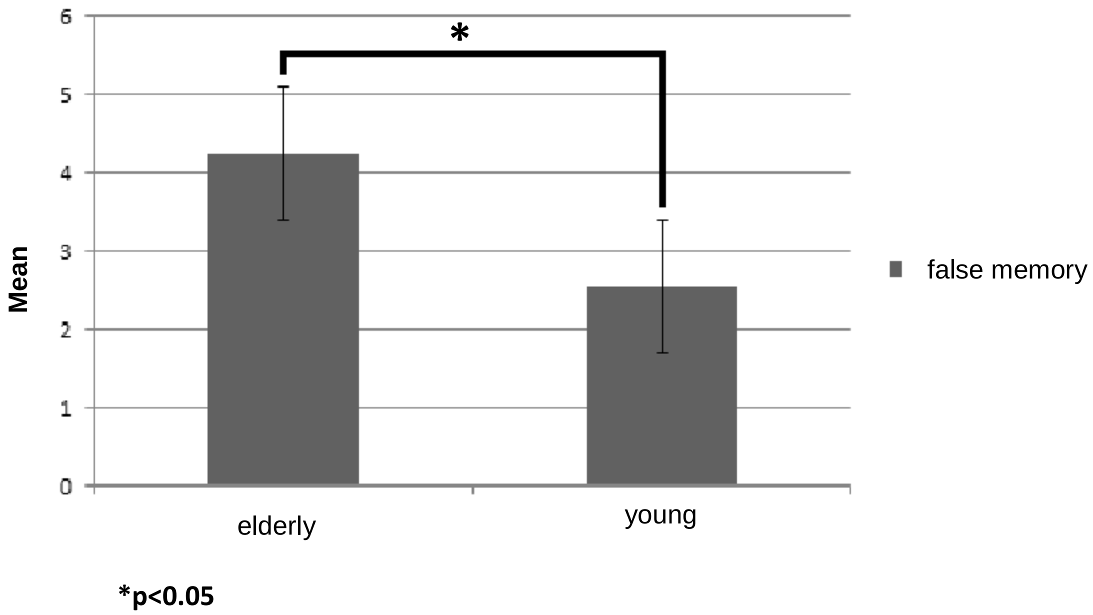


Figure 8.3 – Mean and standard error of false memories formed in group of elderly and young participants.

The mean number of false memories formed by elderly participants was 4.25. This is almost twice as many false memories as formed by younger participants (Mean = 2.34).

An independent-samples t-test was carried out, where the number of false memories was the dependent variable and age group (young vs. elderly) was the independent variable. The analysis revealed that this difference in false memories formed to be statistically significant between the two age groups, $t(47) = 2.3$, $p<0.05$ with elderly participants forming significantly more false memories than younger participants. See Chapter 10 for more discussion of the false memory data.

8.3.5 Age as a predictor of OIs

Age was also looked at as a continuous variable to investigate whether it could ***predict*** the number of OIs formed by the participants. In order to analyse this, the data from the experiment of Chapter 6 and this data were combined and a simple regression was carried out with age in years (age range = 20 – 83 years) as a predictor variable and number of OIs formed as the outcome variable (the variable was created from totalling OIs formed in meaningful, meaningless and communicative conditions). The results indicated that age is not a significant predictor of the number of OIs formed.

However, the multiple regression model of age as a predictor variable and type of actions as the outcome variables significantly predicted the number of OIs after observing only communicative actions ($F(3, 44)= 4.93$, $p<0.05$). The relationship was moderate ($R=0.52$) ($t(44)= 3.44$, $p=0.001$ 99% CI 2.24 – 8.62). This means that as the age of participants increased, the number of OIs for communicative actions also increased. Age did not significantly predict OI for either meaningful or meaningless actions ($p<0.05$).

8.4 Discussion

8.4.1 Aim of the study

The aim of this study was to investigate the formation of OIs in a group of elderly participants. As in the previous experiments, the number of OIs formed after observing meaningful, meaningless and communicative actions was investigated. Based on the previous research on source monitoring errors in the elderly (Haj et al., 2012; Mitchell et al., 2002) it was hypothesised that elderly participants will form significantly more actions than younger participants. This was further supported by the results of this study. Since the mean OI number was found to be small in Experiment 1 of Chapter 6 with many participants scoring at the floor level, one aim of this study was to create a paradigm that will allow for better investigation of OI errors by possibly generating greater mean OIs.

8.4.2 Summary of findings

The main findings are that (i) elderly participants formed significantly more OIs overall than young participants, demonstrating that it is a good cohort to use to study OIs, (ii) that elderly participants show the same pattern of OIs with respect to action type and (iii) that when compared with the young adult sample, elderly participants formed significantly more OIs than young participants after observing communicative actions.

In terms of correct attribution of an action to its source, elderly participants correctly recalled significantly more communicative than meaningful and meaningless actions. This is interesting as they also made more OI errors for this type of action.

It was also found that the age of participant significantly predicts the OI for communicative actions, i.e. the older the participant, the more likely they are to form OIs for communicative actions. Age was not found to be a significant predictor of OIs after observing meaningful and meaningless actions.

The results of current study support the initial hypothesis in that more OIs were made in the group of elderly participants than young participants. Additionally the highest number of OIs formed following observation of communicative actions further supports the hypothesis. Since the communicative emblems used in the present experiments have been shown to elicit similar brain activation as when speech and other communicative movements are processed (Andric et al., 2013), this could result in easier misattribution of these actions as self-performed. Observation of communicative actions does not only trigger similar motor activation as when the action is produced, but is also familiar to participants and therefore could be another factor in the highest rates of misattribution. This could also be the explanation for the lowest number of OIs being formed after observing meaningless actions; since these are the least familiar and not stored in LTM therefore one is not mapping the action repertoire to their own motor system and thus is less likely to recall it as a self-performed action. Research on imitation of actions has demonstrated that familiar and meaningful actions show imitation advantage over meaningless actions (Rumiati and Tessari, 2002). Although there is little research on mirror neurons and elderly, it could be speculated that the same mechanisms are responsible for heightened attribution of communicative actions as self-performed. Perhaps general memory decline related to progressing age results in increased rates of OIs formed for these actions. Furthermore, the results are in line with the literature on memory accuracy decline with age (Husain et al., 2012, Haj et al., 2012, Norman and Schacter, 1997, Schacter et al., 1997). The results show that elderly participants formed significantly more OIs after observation of communicative actions than younger participants (Experiment 1, Chapter 6).

Interestingly, the highest number of correctly attributed self-performed actions was following execution of communicative actions. Communicative actions also resulted in highest number of OIs in the current study. It is unclear as the highest score of correct attribution would suggest that communicative actions are remembered better than meaningful and meaningless actions and possibly result in stronger memory trace. The high level of misattributions of these actions suggests that the memory trace for communicative actions could be in fact strong, but the source attribution mechanisms are not working effectively.

As predicted, observation of meaningless actions resulted in the lowest number of OIs, which could be due to a lack of storage of these actions in the LTM causing these actions to be unfamiliar to participants (Rumiati and Tessari, 2002). This could make the actions seem more unlikely to have been performed to participants and less likely to result in misattributions of self-performance. Furthermore, research on mirror neurones shows that observation of meaningless actions results in little to no mirror neurone activity when compared to goal-directed actions (Husain et al. 2012).

Regarding the meaningful actions, previous research on mirror neurone activity show that observation of meaningful actions results in lower (Ferrari et al., 2005) or the same mirror neurone activation as communicative actions (Montgomery et al. 2007). Additionally, Carmo and Rumiati (2009) found that communicative emblems are imitated better than goal-directed meaningful actions, possibly because of absence of objects in communicative actions. The objects in meaningful actions could pose a greater cognitive processing demand when compared to communicative actions, execution of which does not involve objects. Also in the case of current study, the presence of objects could have made the meaningful actions more distinctive, hence resulting in a more accurate memory trace and correct source attributions as observed.

The results of this study are also in line with the results of Lindner and Davison (2014) who also found OI effect in elderly and young participants. Similar to Lindner and Davison's (2014) study, the current experiment found that elderly participants formed significantly more OI errors than younger adults.

Additionally, the results revealed that elderly participants formed significantly more false memories for action statements that were neither presented to them nor performed by them than younger adult participants. This is in line with previous research on false memory and age, which shows that memory accuracy declines with age (e.g. Hamajima et al., 2005; Dennis et al., 2007).

Future research should examine the OI effect in AD patients as previous research has shown that AD disease patients exhibit heightened susceptibility to form false memories (Plancher et al., 2009) and source monitoring errors (e.g. Haj et al., 2012). Importantly, future studies on OIs should focus on adapting the OI paradigm as a possible tool for early detection of AD, since it has already been shown that source monitoring tests can be used for this purpose (Koide et al., 2010).

8.5 Summary

Previous research on memory errors suggests that source memory accuracy declines with age (Mitchell et al., 2002, Norman and Schacter, 1997). In this study, it was hypothesised that observation of actions of different types will result in higher numbers of OIs formed by elderly participants as compared to young adults. The results showed that elderly participants formed more OIs. The highest number of errors formed was after observation of communicative actions. The effect is attributed to possible mirror neurone activity, resulting in source confusion due to similar neuronal activity during execution and observation of actions. The results are in line with previous research on OI and the elderly (Lindner and Davison, 2014), and source monitoring literature (e.g. Haj et al., 2012).

Future research should examine the OI effect in AD patients as they exhibit high levels of SME formation (Haj et al. 2012, Koide et al., 2010). Possible applications of research in AD cohort could result in adapting the paradigm as an early disease detection tool.

9.5.1 Highlights

- Past research shows deficits in source monitoring accuracy for healthy elderly (Haj et al, 2012; Mitchel et al., 2002; Hastroudi et al., 1989)

- The current study aimed to investigate the patterns of OI formation in the elderly cohort.
- Potentially higher rates of misattribution would allow for developing the OI paradigm better since the mean OI recorded in Experiment 1 were relatively low.
- The present study found the highest number of OIs formed for communicative actions in the healthy elderly.
- Higher number of OIs was formed in the group of healthy elderly than young adults.
- Significantly more OIs were formed after observation of communicative actions in the group of elderly than younger adults.
- The effect is attributed to possible underlying mirror neurone activity resulting in similar brain activation during observation and execution of actions.
- Similarity in neuronal activation could result in confusion between the sources of memory in participants.
- This seems to be supported by the inflation in memory error formation for communicative actions.
- Results of this study showed similar results to those of Experiment 1 (Chapter 6). However, significantly more OIs were made in the current study. Additionally, in the current study significantly more communicative than meaningful and meaningless actions resulted in OIs, when in Experiment 1, observation of communicative and meaningful actions was equally likely to result in OIs.
- It was found that as the age of participant increases, so does the number of OIs formed, but only after observing communicative actions.
- Age was not found to be a significant predictor of OIs for meaningful and meaningless actions.
- Not only did the observation of communicative actions resulted in the highest level of OIs but also in the highest number of correct source attributions of self-performed actions.
- Future research should consider testing the OI paradigm in AD patients.

Some of the information from this chapter can be found in Mitrenga et al. (in prep.) – ‘Observation Inflation in the cohort of elderly participants’.

Chapter 9

The role of instruction in the formation of observation and self-action inflations

9.1 Introduction

In the previous chapters (Chapter 6, Chapter 7 and Chapter 8), it was found that both the observation and execution of actions can result in SMEs where the attribution of the source of action is incorrect. In Experiment 1 and Experiment 3 (OI), it was found that source confusions of performing an action can be created by observing actions being performed by somebody else. These OIs were first shown by Lindner et al. (2010), who found that observation of meaningful actions results in more false memories of self-performance than when action statements are read. However in the study of Chapter 6 and the study of Chapter 8, OIs were investigated with different types of actions (meaningful, meaningless and communicative). In Experiment 1 (Chapter 6) it was found that significantly more OIs were made after observing communicative actions as compared to meaningless actions. Although more communicative than meaningful actions resulted in OIs, this difference was not significant. This difference has reached significance in Experiment 3 (Chapter 8) where OIs were investigated in the elderly cohort (mean age = 72.87). Observation of communicative actions resulted in significantly more OIs than observation of meaningful and meaningless actions. Additionally it was found that, the elderly participants in Experiment 3 formed significantly more OIs than young participants in Experiment 1. The OI effect was also found to degrade as the time between the experiment and study phase progressed in both Experiment 1 and 3, which is in line with previous research on source confusion errors (e.g. Porter et al., 2010). The OI effect has not been researched extensively, but the previous research in this subject area hypothesises that the effect is a consequence of mirror neurone activity and source monitoring failure (Lindner et al., 2010; Schain et al., 2012). The results of Experiment 1 (Chapter 6) and 3 (Chapter 8) supported the hypothesis as the highest number of OIs was formed after participants observed communicative actions. It was found that the lowest number of OIs was formed after observation of meaningless actions which also supports the initial hypothesis.

To further test possible involvement of mirror neurones, a similar experiment was conducted (Chapter 7) with the hypothesis that if mirror neurones are involved in OIs (misremembering observed actions as performed), they should also be involved the other way i.e. in misattributing performed actions as observed. Instead of asking the participants which actions from the experiment they remembered *performing*, participants were asked which actions they remembered *observing*. The results showed that execution of actions **can** also result in SMEs, where performed actions are misremembered as observed actions. This has been termed self-action inflation (SAI) (Mitrenga et al., in prep), as the self-performed actions are remembered to be from a different source. The pattern of SAIs was interesting. It was found that significantly more meaningless and communicative actions resulted in SAIs than meaningful actions. Meaningless and communicative actions were equally likely to result in SAIs (although more meaningless actions than communicative resulted in SAIs, the difference was not statistically significant). The effect was attributed to deficits in motor memory due to lack of expertise in performing those actions in everyday life (meaningless). The unfamiliarity of meaningless actions could result in a feeling of not being able to have had performed these actions, as their character and attributes seem unconventional. This is supported by previous findings on imitation of meaningless actions (Rumiati and Tessari, 2002).

However, the inflation in misattributions for meaningless actions is against the initial mirror neurone hypothesis proposed for this effect. It was expected that a similar pattern of SAIs will be formed to the one in the Experiment 1 (OI) and 2, due to similar mirror neurone activity elicited by observation of actions as in the execution of these actions. Since communicative and meaningful actions have been shown to trigger greater mirror neurone activation than meaningless actions (e.g. Montgomery et al., 2007; Husain et al., 2012), a higher level of misattribution for these actions was also expected to be found in the Experiment 2. It is likely that this is the result of a methodological issue hiding a potential finding and a further investigation is needed to study this. The exact same actions were used in the experimental phase of both experiments, only the wording of the questionnaire changed between the two. It would therefore appear that there is a strong bias or priming effect created by the wording of the two questionnaires. Whether this is hiding an effect of mirror neurone activity, enhancing it or negating it remains unclear at this stage. This issue will be addressed in this chapter where the methodology and the mode of retrieval for source memories was controlled in the current experiment.

An example of how the retrieval method can influence the results was demonstrated by Lindsay and Johnson (1989). They found that changing the instructions at the retrieval stage eliminated the effect of suggestibility in a false memory study. In the experiment, participants observed scenes and following that read a narrative suggesting false information about the previously presented scene. Later, participants answered questions about their memory for the items that were presented in the scene in either picture or narrative presentation. The participants either (i) replied with 'Yes' or ‘No’ as to whether they saw the item previously or (ii) took a source monitoring questionnaire. In the source memory questionnaire they were required to decide whether (i) they had seen the item in the picture; (ii) the item was only present in the text; (iii) the item was present in both picture and text or (iv) the item was not presented in any modality. The results revealed that the source monitoring questionnaire eliminated a suggestibility effect and misattribution of the false information, which was present when participants answered with the 'Yes'/'No' paradigm. Lindsay and Johnson (1989) suggested this happens because when participants answer with 'Yes'/'No' they make the judgement about the item based on feelings of familiarity. On the other hand, when presented with source memory options, they evaluate the item based on the information specific for a given source.

Therefore, the study of this chapter will give participants the option to retrieve the information about the particular source of the action – either observed or performed, instead of recognition of just one source, as was done in Experiment 1, Experiment 2 and Experiment 3.

9.1.1 Aims and hypothesis

Experiment 1, 2 and 3 showed that it is possible to create source confusion errors from short observation of actions along with performing actions, as well as attributing one's own actions to a different source. In the OI experiments (Chapter 6 and 8), as well as in the SAI experiment (Chapter 7), an adapted version of R-K-G paradigm was used to investigate the memory errors. In the OI experiments, participants were asked to specify which actions they recall *performing* whereas in the SAI experiment they were asked to specify the actions they recall *observing.* Note that other than the wording of the questionnaire, the experiments were the same. As demonstrated in the research introduced in Chapter 2, memory is highly susceptible to suggestions and misinformation (Loftus et al. 1978). Given the discrepancy between the results for OI and SAI and the fact that significantly more errors were made for the SAI experiment (Chapter 7) as compared to the OI experiment of Chapter 6 ($p<0.05$), this experiment will test both source memory errors (OI and SAI) with a questionnaire that involves participants recalling the source themselves i.e., they were given the name of the action and then asked to choose themselves whether they recall observing or performing that particular action. The rest of the experiment was the same as the OI experiments (Chapter 6 and 8) and the SAI experiment (Chapter 7).

The hypothesis for this experiment is that assuming the involvement of mirror neurones in motor memory and the SMEs then a similar pattern of misattributions across the different types of actions for both observed and performed is expected. This means that if the observation and execution of actions results in similar neuronal activation, the experience of performing and observing would be similar and the level of misattribution produced for these actions potentially similar. Given the discrepancies between the OI and the SAI experiments, likely to be because of bias or suggestibility from the questionnaire, this experiment also acts as a controlled paradigm to avoid any methodological issues hiding any potential effect**.**

9.2 Methods

9.2.1 Participants

Twenty-four participants recruited from University of Bradford took part in the experiment (mean age = 27.04). Four males (mean age = 24) and 17 females (mean age = 27.94) took part. The inclusion criteria were no uncorrectable visual impairments and no history of autism. The participants were different from those that had participated in Experiments 1 (Chapter 6), Experiment 2 (Chapter 7) and Experiment 3 (Chapter 8). Ethical approval was obtained from Humanities, Social and Health Sciences Research Ethics Committee at University of Bradford.

9.2.2 Design

A within-subjects design was used, where dependent variables were (i) the number of OIs or SAIs formed and (ii) the correct source attributions of performed and observed actions. The independent variables were the types of actions which participants were exposed to in a video presentation, either (i) meaningful, (ii) meaningless or (iii) communicative actions. These are the same videos and PowerPoint presentation as used in Experiment 1 (Chapter 6), Experiment 2 (Chapter 7) and Experiment 3 (Chapter 8).

9.2.3 Materials

The same materials used for Experiment 1 (Chapter 6), Experiment 2 (Chapter 7) and Experiment 3 (Chapter 8) were used here. The difference in the experiment was the questionnaire given to participants. This time the items in the questionnaire consisted of sentences written in the impersonal form for example, 'flashing a torch' and the questions asked whether the participant remembered *observing* the actions or *performing* the actions which they simply had to tick. Additionally, participants were instructed to decide whether they 'Remember', 'Know' or 'Guess' that they either performed or observed each action (see Appendix 3 for a copy of the questionnaire used in the study). The sentences contained 30 actions that participants performed and 30 actions that they had observed in the PowerPoint presentation. As for Experiment 2 (Chapter 6), Experiment 2 (Chapter 7) and Experiment 3 (Chapter 8), 20 actions that were neither observed nor performed were added to the questionnaire in order to test real false memories.

9.2.4 Procedure

The same procedure was used as in the OI and SAI experiments with young participants. The only difference in the procedure was the time delay after which the participants filled in the source memory R-K-G questionnaire. Here, the time delay was two weeks for all the participants.

9.3 Results

The aim of this experiment was to investigate the formation of OIs and SAIs as a result of action observation and action execution for different types of actions, when recalled through a single questionnaire where the participants themselves had to recall the source of the action. The OI and SAI scores were, as for the previous chapters, created by summing 'Remember' and 'Know' responses for each action. The 'Guess' responses are discussed in detail in Chapter 10. Figure 9.1 shows the number of OIs and SAIs formed. The OIs are the number of misattributions of observed actions as the ones that were self-performed and SAIs are the number of misattributions of self-performed actions as ones that were observed.

9.3.1 Observation Inflation and Self-action Inflation

The results show that the highest number of errors was the OIs after performing communicative actions. A similar pattern was observed for the SAIs, where the highest number of errors was formed for communicative actions (see Figure 9.1).

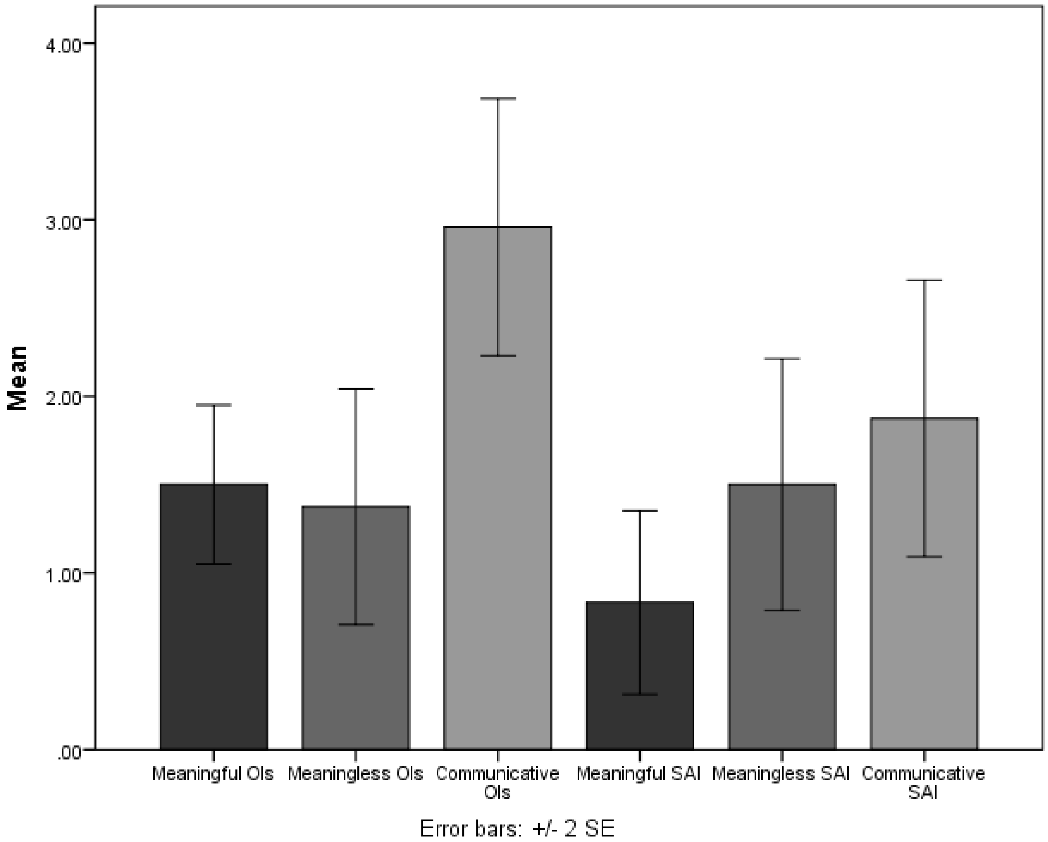


Figure 9.1 – Mean and standard errors for OIs and SAI formed after observation and execution of meaningful, meaningless and communicative actions.

9.3.1.1. Analysis of action type (independent of error type)

The assumption of normality has not been met for the sample conditions Standard parametrical tests were carried out alongside non-parametric test. For this section both analyses showed the same results. The parametric analysis is reported.

Formal analysis with a 3 (action type: meaningful vs. meaningless vs. communicative) x 2 (error type: OI vs. SAI) repeated-measures ANOVA revealed that there was a significant main effect of the action type, $F(2, 46) = 13.56$, $p<0.001$. This means that there was a significant difference in the number of errors formed for different types of actions regardless of the error type (OI or SAI). The pairwise-comparisons revealed that there was a significant difference between the errors formed after observing and executing communicative and meaningful actions ($p<0.05$) and communicative and meaningless actions ($p<0.05$). No significant difference was found between meaningful and meaningless actions ($p>0.05$). This shows that regardless of whether the participants recalled the actions as observed or performed, they were most likely to form errors for communicative actions.

9.3.1.2 Analysis of error type (OI and SAI)

There was no significant main effect found between the number of OIs and SAIs formed ($p>0.05$). This means participants were equally likely to form both types of errors when asked to specify whether they observed or performed an action.

There was no significant interaction formed between the action type and the error type ($p>0.05$) which means that the number of OIs and SAIs formed for the different types of actions was similar.

9.3.2 Comparisons with the results of Chapter 6 and 7

The results of Experiment 1 (OI, Chapter 6) showed a mean score of all errors to be 3.93 (SD = 3.23) and the results of Experiment 2 (SAI, Chapter 7) showed a mean score of all errors to be 12.71 (SD = 6.71). Statistical analysis with independent-samples t-test revealed that significantly more SAIs were made than OIs ($p<0.001$; see Chapter 6 and 7 for more details). Interestingly, in the current experiment there was no significant difference found in the number of OIs and SAIs formed ($p>0.05$), showing that once the questionnaire bias was eliminated the difference disappeared.

9.3.3 Correct recall

The primary aim of this study is to investigate the OI and SAI errors, however, as in the two previous chapters, the correct recall is also important to report since it provides more information on overall source attribution. The other results obtained from the experiment were the (i) *observed correct* – where the participants observed the action in the experiment and subsequently recalled it as observed in the questionnaire; (ii) *performed correct* – when the participant performed the action and correctly recalled it as performed.

Table 9.1 – Mean and standard deviations of actions where the source is correctly identified

Source	Action Type	Mean	Standard deviation
Performed correct	Meaningful	4.46	1.47
	Meaningless	6.88	3.11
	Communicative	6.29	2.09
Observed correct	Meaningful	2.13	2.17
	Meaningless	4.13	2.38
	Communicative	3.08	2.19

Table 9.1 shows that the highest number of correctly recalled actions as performed was for the meaningless actions and communicative actions. The lowest number of actions correctly recalled as performed was for meaningful actions.

The highest number of actions correctly recalled as observed was in the meaningless condition, followed by communicative and meaningful.

9.3.3.1 Analysis of action type (independent of source)

Formal analysis with a three (action type: meaningful vs. meaningless vs. communicative) x two (correct source type: performed vs. observed) repeated measures ANOVA revealed a significant main effect of action type $F(2,46) = 21{,}54$, $p<0.001$. Pairwise-comparisons showed that significantly more meaningless than meaningful actions ($p<0.001$) were recalled with their correct source overall, and significantly more communicative than meaningful actions were recalled correctly ($p<0.001$). This means that regardless whether participants correctly recalled self-performed or observed actions, they were more likely to recall either meaningless or communicative rather than meaningful actions.

9.3.3.2 Analysis of source (regardless of action type)

The analysis also found a difference in the number of correct answers given for performed and observed actions, $F(1.23) = 29.63$, $p<0.001$, showing that more performed actions were recalled correctly as performed than observed actions were recalled correctly as observed. This suggests that participants are better at remembering actions they performed themselves than observed others performing.

There was no significant interaction between the type of actions participants were exposed to, and the memory source (performed or observed). This means participants were equally correct with the recall of specific types of actions that were observed and performed.

9.3.4 Comparing OIs from Experiment 1 and the current experiment (Chapters 6 and 9)

This section investigates whether the pattern of OI formation between Experiment 1 and the current study differed, given the controlled methodology of the current chapter.

Table 9.2 – Mean and standard deviation of OIs in Experiment 1 and current experiment.

Action type	Experiment	Mean	Standard deviation
Meaningful	Experiment 1	1.17	1.34
	Current Experiment	1.5	1.1
Meaningless	Experiment 1	0.92	1.15
	Current Experiment	1.38	1.64
Communicative	Experiment1	1.83	1.58
	Current Experiment	2.96	1.78

Table 9.2 shows that the highest number of OIs formed in both experiments was after observation of communicative actions. The lowest number of OIs in both experiments was formed after observation of meaningless actions.

The results of non-parametric tests are reported for the comparison of OI recall between Experiment 1 and Experiment 3.

The analysis with Friedman's test showed that there was a significant difference in the number of OIs formed after observing the three different types of actions in Experiment 1 and Experiment 3, $\chi^2(3) = 42.86$, $p<0.001$. Post hoc analysis with

Wilcoxon signed-rank tests was conducted with Bonferroni correction applied, resulting in a significance level set at $p<0.005$. The results of Wilcoxon signed-rank tests revealed that significantly more OIs were formed for communicative actions in Experiment 3 than meaningful actions ($Z = -3.34$, $p<0.001$), meaningless actions ($Z = -4.02$, $p<0.001$) and communicative actions ($Z = -3.56$) in Experiment 1.

9.3.5 Comparing the results of SAIs in Experiment 2 (Chapter 7) and the current experiment (Chapter 9)

This section investigates whether the change in methodology had any effect on the pattern of SAI formation between Experiment 2 and the current study (Experiment 4, Chapter 9).

Table 9.3 – Mean and standard deviations for all action type in Experiment 2 and the current experiment.

Action type	Experiment	Mean	Std. Deviation
Meaningful	Experiment 2	2.5	2.05
	Current Experiment	0.83	0.91
Meaningless	Experiment 2	5	3.09
	Current Experiment	1.5	1.7
Communicative	Experiment 2	4.6	2.27
	Current Experiment	1.88	1.92

Table 9.3 shows that the highest number of SAIs was formed for communicative actions in the current experiment (Chapter 9) and for meaningless actions in Experiment 2 (Chapter 7).

The parametric tests are reported for this section.

This was analysed with a 2x3 mixed measures ANOVA, where the between subject factor was the number of SAIs formed in Experiment 2 (Chapter 7) and the current experiment (Chapter 9) and within-subject factor was the action type (meaningful, meaningless and communicative). The analysis revealed a significant main effect of action type, suggesting a different pattern of SAIs formed for different action types overall, $F(2, 104) = 26.92$, $p<0.001$.

The pairwise-comparisons revealed that significantly more SAIs were formed after performing communicative actions than meaningful actions ($p<0.001$). There was also significantly more SAIs formed for meaningless actions than meaningful actions ($p<0.001$). There was no significant difference in the number of SAIs formed between meaningless and communicative actions ($p>0.05$), which means participants were equally likely to misattribute self-performed meaningless and communicative actions as performed by somebody else in both experiments.

It was also found that significantly more SAI errors were formed in Experiment 2 than the current study $F(1, 52) = 25.7$, $p<0.001$.

Furthermore, the results revealed a significant interaction between the action type and the experiment, $F(2, 104) = 6.7$, $p<0.05$, which means that there was a different pattern of SAIs for given action type in the two experiments. Further analysis with independent-samples t-tests revealed that significantly more meaningful actions ($t(49) = 3.73$, $p<0.001$), meaningless actions ($t(47) = 5.25$, $p<0.001$) and communicative actions ($t(52) = 4.75$, $p<0.001$) were formed in Experiment 2 than in the current study (Experiment 4).

9.3.6 False memory

False memories for actions that were neither observed nor performed in the experiment were studied. It was found that participants formed similar number of false memories of observation (mean = 3) and performance (mean = 2.54) of actions. The paired-samples t-tests did not reveal a significant difference in the number of false memories formed for either observation or performance ($p>0.05$).

9.4 Discussion

9.4.1 Aims of the study

This experiment aimed to investigate source memory errors further where participants observed and performed a series of meaningful, meaningless and communicative actions and then had to recall themselves whether they had either performed or observed the said action. This acts as a control study for Experiment 1 (Chapter 6), Experiment 2 (Chapter 7) and Experiment 3 (Chapter 8) where there appeared to be a strong bias from the wording of the questionnaire.

9.4.2 Main findings

The results showed that significantly more source confusion errors (OIs and SAIs) were formed after executing or observing communicative actions than meaningful and meaningless actions. No significant difference in the number of source memory errors was found following execution and observation of meaningful and meaningless actions. The total number of OIs and SAIs did not differ significantly, suggesting a similar pattern for both errors, as initially expected.

As for the actions that were correctly attributed to their source, the source of meaningless and communicative actions was more likely to be correctly recalled than meaningful actions. Significantly more communicative and meaningless actions were correctly recalled than meaningful actions. Communicative and meaningless actions were equally likely to be correctly recalled to their sources. Even though this suggests that recalling the source of meaningful actions is hardest it is interesting that the meaningful actions do not provide the highest numbers of OIs and SAIs. This suggests a potentially weak memory trace for meaningful actions resulting in low number of misattributions as well as correct attributions.

The OIs formed in this study and that of Experiment 1 (Chapter 6), were the highest after the observation of communicative and meaningful actions. Significantly higher mean number of OIs were formed in this experiment for communicative actions than communicative, meaningful and meaningless actions in Experiment 1, showing that this methodology is a better method of inducing these source memory errors.

As for the SAI errors, the results revealed that more communicative and meaningless actions than meaningful actions resulted in formation of misattributions regardless of experiment. Furthermore, the results revealed that all action types resulted in higher mean SAI in Experiment 2 than in the current study. Interestingly, the pattern of SAIs in Experiment 4 did not show as high a level of SAIs formed for meaningless actions as in Experiment 2, again showing that the methodology, in this case the wording of the questionnaire, has a strong influence on the formation of these errors.

9.4.3 Mirror neurones and memory errors (OIs and SAIs)

The results support the evidence of possible mirror neurone involvement by showing inflation of both types of errors for communicative action type. As discussed in the previous chapters, observation of communicative emblems results in activation of motor areas that are also active when the same actions are performed (Andric et al., 2013). Past research on mirror neurones has shown that observation of communicative actions shows greater activation of brain areas thought to be associated with mirror neurone activity (e.g. Donne et al., 2009, Andric et al., 2013).

9.4.5 Wording of source memory questionnaire

This study implemented a paradigm that controlled for suggestibility of the instructions given at the retrieval stage. Participants had to decide for themselves in a recall task as to whether they had performed or observed an action.

In Experiment 2 where it was found that the highest number of SAIs were formed for meaningless and communicative actions, participants had to decide whether they recall observing the actions to have been performed in the video presentation. They did that by initially answering ‘Yes’ or ‘No’ and if their answer was ‘Yes’ they further specified whether they ‘Remember’, ‘Know’ or ‘Guess’ that they observed the actions being performed. According to Lindsay and Johnson (1989), ‘Yes’/’No’ recognition is based on feelings of familiarity. Thus, it is plausible that the high inflation in misattributions of meaningless actions could be a consequence of lack of familiarity of these actions even if they were self-performed and attributing them to others. However in the current study where the method of retrieval in the questionnaire was changed to a source monitoring questionnaire where participants had to decide about the source of particular memories, the mean number of SAIs for meaningless actions was significantly lower ($p<0.001$). This could be because participants engage in memory source evaluation for each source separately (Lindsay and Johnson, 1989).

As discussed in the chapter on SAIs (Chapter 7), where more SAIs were made than OIs (Chapter 6), it was hypothesised that this result is because we are better at remembering items we ourselves have performed than what someone else has performed hence when the phrasing of the questionnaire is ***I performed*** (methodology for the OI chapter, Chapter 6) our recall system is more efficient than when the question is phrased ***I observed*** (methodology for the SAI chapter, Chapter 7) and the participant needs to remember what someone else has done. The present study eliminated this bias and showed that using a simple source memory recall task, both OIs and SAIs were equally likely to be formed. The participant needs to recall the action and the source themselves which is harder than recognition (e.g. Cabeza et al., 1997), as was required of them in Experiment 1, 2 and 3.

9.5 Summary

The study partially replicated the findings of Experiment 1, 2 and 3, in that it is plausible to form memory errors of self-performance (OI) after observing someone else performing an action and memory errors where self-performed actions are misattributed to other people (SAI). It was found that significantly more communicative than meaningful and meaningless actions resulted in source monitoring errors. The OI results are partially in line with the results of Experiment 1 but the SAI results are not in keeping with Experiment 2, where a high level of SAIs was formed after execution of meaningless actions. Participants formed a similar number of OIs and SAIs in the current experiment which was against what was found in Experiment 1 and 2, where significantly more SAIs where formed in Experiment 2 than OIs in Experiment 1. Importantly the change in methodology highlights the need for a controlled paradigm in research into SMEs and emphasises the strength of suggestibility in this sort of research. The results also provide support for the mirror neurone hypothesis as observation and execution of communicative actions resulted in the highest number of source memory errors (OIs and SAIs).

9.5.1 Highlights

- Previous experiments of this thesis found that observed actions can be misattributed as self-performed (OI); and self-performed actions can be misattributed to having been performed by other people (SAI).
- It was proposed to be a result of source monitoring being more challenging due to mirror neurone activity.

- The hypothesis for this study was that the same pattern of OIs and SAIs will be found when participants recalled the source of their memory themselves, which supports the mirror neurone hypothesis.
- The experiment further controls for any methodological issues hiding any potential effects (since the mirror neurone hypothesis was not fully supported by the results of Experiment 2).
- Significantly more errors (OI and SAI) were made following observation and execution of communicative actions than meaningful and meaningless actions.
- OIs and SAIs were equally likely to be formed supporting the initial hypothesis.
- No specific action type resulted in higher formation of OIs or SAIs.
- Significantly more OIs were formed in Experiment 4 than 1.
- Significantly more SAIs were formed for all action types in Experiment 2 than Experiment 4.
- Results support the hypothesis that mirror neurones may stand behind OI and SAI formation, as the results show that both action and execution result in source misattributions. In particular, the high level of misattributions formed for communicative actions may suggest mirror neurone involvement in the OI and SAI effects.
- Results highlight the importance to control for suggestibility from questionnaires in source memory error research.

Some of this information can be found in Mitrenga et al (in prep.) – 'The role of instruction in the formation of observation and self-action inflations'.

Chapter 10

The recollective experience of OIs and SAIs. A study of R-K-G responses

10.1 Introduction

In Experiment 1 (Chapter 6), Experiment 3 (Chapter 8) and Experiment 4 (Chapter 9), the misattribution of observed actions as self-performed were investigated (OIs). The SAI effect, where self-performed actions are misattributed as being performed by other people was also examined in Experiment 2 (Chapter 7) and Experiment 4 (Chapter 9). In these experiments, participants filled in a source memory questionnaire which employed the R-K-G paradigm. Participants had to specify whether they 'Remembered', 'Knew' or 'Guessed' that they had performed (OI) or observed (SAI) the actions. To calculate both OIs and SAIs in the previous chapters, the 'Remember' and 'Know' responses were totalled, excluding 'Guess' responses which are thought to indicate no recollection (Horry et al., 2010). The OI and SAI chapters were discussed in relation to the type of actions, importance of instruction type and age differences in formation of misattributions. The current chapter focuses specifically on the recollection types (separate R-K-G responses) participants had for the misattributions they formed (OIs and SAIs) as well as for the correctly recalled actions (correctly recognised as self-performed and correctly recognised as having been performed by others). Studying the nature of memory recollection is important as different recollection types are indicative of the type of memory process used (Gardiner et al., 2002). For example, 'Remember' recollection suggests a stronger memory trace than 'Know' or 'Guess' recollections (Geraci and McGabe, 2006). See section 10.1.1 below for a brief recap of the R-K-G literature and Chapter 5 for a thorough review. In the present chapter, the recollections for observed and performed actions made with (i) ‘Remember’, (ii) ‘Know’ or (iii) 'Guess’ responses will be analysed. The datasets used will be from Experiments 1, 2, 3 and 4.

10.1.1 Types of memory recollections

The R-K-G questionnaire is a widely used tool which measures different types of conscious memory recollection (Gardiner et al., 2002). Tulving (1985) firstly proposed the ‘Remember-Know’ (R-K) paradigm as a method of distinguishing between two memory types; episodic and semantic memory. According to Tulving (1985), the 'Remember' responses indicate retrieval of episodic memories which contain autobiographical information as well as the qualitative details related to the memory. Remember indicates that a person can mentally 'relive' the memory, and recall specific details about it. The 'Know' response on the other hand, is associated with feelings of familiarity in relation to the memory and a sense of 'knowing', but lacks detail about the information or event. Hence, 'Know' responses are more likely to express semantic memories (Tulving, 1985). Since the development of the R-K paradigm, it has been widely used in memory research to investigate the types of memory recollections and confidence judgments (e.g. Geraci and McCabe, 2006; Mather et al., 1997; Arnold and Lindsay, 2007; Dunn, 2004). See Chapter 5 (Sections 5.2 and 5.3) for a more detailed introduction to the paradigm.

Furthermore, past research suggests that recollection and familiarity engage different neural structures in the brain. For example, Yonelinas et al. (2005) investigated the neural activity during the retrieval of words in an fMRI study. In the experiment, participants first saw 150 words (e.g. 'harp') and following this took a memory test in which they had to decide whether they 'Remembered', 'Knew' or 'Guessed' that they had previously seen the displayed words. In addition to the 150 words that they had previously seen, 150 new words were added to the list that had not been shown to participants previously. Yonelinas et al. (2005) found that recollection ('Remember' responses) and familiarity ('Know' responses), activated different brain areas. 'Remember' responses were associated with activity in the anterior medial prefrontal cortex and 'Know' responses with left lateral prefrontal cortical activity. This finding is important because it highlights the distinctiveness between the two recognition memory types. It shows that the 'Remember' responses are not simply a reflection of high levels of familiarity one has, but a retrieval of specific details associated with the memory (Yonelinas et al., 2005). Given that this thesis specifically looks at 'inflations' which are SMEs, it is important to now investigate *how* these errors are remembered/misremembered and which recognition types are being used by participants when they are making inflations. Importantly, do these recognition types differ between different types of actions (meaningful, meaningless and communicative) when a participant makes an inflation? Is there a difference between recollection type for OIs and SAIs?

Regarding specifically the recollection and source monitoring for performed and observed actions, Manzi and Nigro (2008) provided 88 action statements to participants describing simple action commands (e.g. 'Put the letter in the envelope'). Participants completed the experiment in pairs, where they took turns performing the actions on the instruction of the researcher. While one of the participants performed the action, the other participant observed, which was then alternated. After either one or two weeks, participants returned and were given a surprise source memory test. The test comprised of the following: (i) initial old/new item recognition (specifying whether the action was encountered in the test phase), (ii) an R-K-G recognition test and (iii) a source memory test. To clarify, in the beginning participants were required to class the given action statements as encountered or not encountered. They then had to decide whether they 'Remembered', 'Knew' or 'Guessed' that they had seen the action before and finally they were asked to attribute the action to its source – either self-performed or performed by the other participant. The results showed that more actions were correctly attributed to their source overall after one week than after two weeks (consistent with the findings of this thesis). After a one week testing delay, participants correctly recalled 84% of all actions (performed and observed). More actions were recalled as 'Remembered' (60%) than 'Known' (24%); and more performed actions (89%) were correctly attributed to their source than observed actions (80%). After a two week testing delay, 76% of actions were correctly attributed to their source with 55% of actions recollected as 'Remembered' and 21% recollected as 'Known'. Both performed and observed actions were equally correctly attributed to their source, the recall showing 76% accuracy for both conditions. To summarise, this means that correct attribution after both testing time delays was more likely to be with 'Remember' responses. As for the actions that were incorrectly attributed to their source (observed actions recalled as performed and vice versa), these actions were equally as likely to be recalled with either ‘Remember’ or ‘Know’. Additionally, Manzi and Nigro (2008) found that observed actions incorrectly recalled as performed were more likely to be recollected with ‘Remember’ than performed actions incorrectly recalled as observed which I term OIs and SAIs respectively.

Although the main objective of Manzi and Nigro’s (2008) study was to investigate the recollection type for correct attribution, their results on misattribution of actions relate to the results reported in this thesis (the misattributions are not specifically named as OI or SAI in the experiment of Manzi and Nigro (2008) however). Manzi and Nigro’s (2008) study supports the claim that observation of actions can result in memories of self-performance (named OI in this thesis and by Lindner et al., (2010)); as well as the notion that actions that were self-performed can be misremembered as performed by somebody else (named SAI in this thesis). Given the examples of the actions used by Manzi and Nigro (2008) (e.g. 'Put a letter in an envelope'), it could be assumed that the actions were of a meaningful nature. The results of Manzi and Nigro (2008) suggest then, that self-performed meaningful actions are more likely to be misattributed to others (SAIs), than actions performed by others as self-performed (OIs). These results are consistent with the results of Experiment 1 (Chapter 6) and Experiment 2 (Chapter 7), where more SAIs were formed in Experiment 2 than OIs in Experiment 2. However, the possible questionnaire bias was not controlled for in these experiments. In the control Experiment 4 (Chapter 7), the results have shown that the number of OIs and SAIs formed was similar. ***Both*** error types were more likely to be recollected as 'Remembered' in Manzi and Nigro’s study (2008). This could suggest that misattributed actions are similarly 'vivid' and equally detailed as real memories (Mather et al., 1997).

10.1.2 R-K-G recollections in the elderly

The age of participants seems to be an important factor in the recollective patterns of information. Aizpurua et al. (2009), tested the R-K-G recollection in a group of elderly (mean age = 62.93) and young participants (mean age = 19.93). The participants were presented with a video depicting a robbery and following that they took a source recognition test and answered whether or not they 'Remembered', 'Knew' or 'Guessed' the action statements described in the test.

The action statements were comprised of true descriptions of the events that were shown in the video and false fabricated statements about the robbery. The results revealed that both elderly and young participants were more likely to recall false statements about the robbery as true with 'Remember' recollections, rather than 'Know' or 'Guess'. However, the elderly recalled almost twice as many false statements as 'Remembered' in comparison to younger participants. Additionally, the correct information about the robbery was more likely to be recalled with 'Remember' responses by both elderly and young participants (Aizpurua et al., 2009). Aizpurua et al. (2009) suggest that elderly participants experience strong feelings of familiarity towards the false statements and judge them as 'Remembered'. Also the age related deterioration of source monitoring abilities could result in the experience of re-living of the true information being misattributed to the false statements (Aizpurua et al., 2009).

10.1.3 Aim of the current chapter

In this chapter, the pattern of memory recollection is investigated for both OIs and SAIs, and action type that were recorded in the experiments in this thesis. In the experimental chapters of this thesis (Chapter 6, Chapter 7, Chapter 8, Chapter 9), the 'Remember' and 'Know' responses were totalled to create an error variable, either OI or SAI. This chapter will now look at these recollections separately, as well as investigate the pattern of 'Guess' recollection which has yet to be formally analysed. The correct recollections of self-performed and observed actions will also be investigated.

Additionally, the 'true' false memory recollections will be discussed and analysed in this chapter. The 'true' false memories are when participants recall either performing (OI) or observing an action (SAI), but in fact they have neither performed nor observed it in the experiment. These were statements included in the questionnaire that had not been in the test phase at any point.

As far as I am aware, mirror neurones have not been researched in relation to R-K-G recollection previously. Mirror neurones have been linked with different types of implicit memory, for example priming (Brass et al., 2001; Press et al., 2005; 2006; 2007) and motor memory (Stefan et al., 2005). The R-K-G paradigm on the other hand, is used to measure explicit memory, and conscious recollection of episodic memory. However, it is not unreasonable to assume that different memory strengths might be seen for different action types if mirror neurones are involved in the source memory errors.

It is not clear what recollective pattern would be predicted here regarding the three action types. However, given the results between Experiment 1 (Chapter 6, 'The observation inflation effect – memory for different types of actions') and 2 (Chapter 7, 'Self-action inflation - misattribution of self-performed actions as observed') showed that significantly more SAIs then OIs were made (which is consistent with Manzi and Nigro's findings (2008)), it is predicted that SAIs will be of a stronger memory trace i.e. more 'Remember' responses. However given the clear bias from the wording of the questionnaire, it is the, R-K-G responses from Experiment 4 Chapter 9 ('The role of instruction in the formation of observation and self-action inflations') that is of particular importance as this can be considered the control condition.

It seems surprising that there is so little research on the R-K-G paradigm in the elderly but based on the study discussed above (Aizpurua et al., 2009), which found that the elderly made more 'Remember' recollections for false memories than 'Know' and 'Guess', it is predicted here that the elderly will make more 'Remember' responses for their OIs than 'Know' or 'Guess' responses as compared to the young. However, the experiment of Aizpurua et al., (2009) was different from the experiments discussed in the thesis, making the two studies difficult to compare.

10.2 Method

10.2.1 Participants

Data sets have come from Experiment 1 (Chapter 6, 'The observation inflation effect – memory for different types of actions'), Experiment 2 (Chapter 7, 'Self-action inflation - misattribution of self-performed actions as observed'), Experiment 3 (Chapter 8, 'Observation inflation in the cohort of elderly participants') and Experiment 4, Chapter 9, ('The role of instruction in the formation of observation and self-action inflations'). All participants were recruited from the University of Bradford except for the participants from Experiment 3, Chapter 8 ('Observation inflation in the cohort of elderly participants'), who were recruited from the Division of Psychology's over 60s cognitively healthy participant pool. Inclusion criteria for all participants were no uncorrectable visual impairments and no history of autism. Ethical approval was obtained for each of the experiments separately, from the Humanities, Social and Health Sciences Research Ethics Committee at University of Bradford.

10.2.2 Design

10.2.2.1 Remember vs. Know responses

The results from the experiments of the previous chapters were based on the totalled 'Remember' and Know' responses. Here I firstly look at the split between the 'Remember' and 'Know' responses and will then go on to investigate the 'Guess' responses. Given the strong differences between the experiments of each chapter, the results from each experiment will be analysed separately. For each set of the results respectively, the dependent variables are (i) the number of OIs recalled with 'Remember' and 'Know; (ii) number of SAIs recalled with 'Remember' and 'Know', (iii) correctly recalled performed actions with 'Remember' and 'Know' (OI experiments) and (iv) correctly recalled observed actions with 'Remember' and 'Know' (SAI experiments). The independent variable is the action type, either (i) meaningful, (ii) meaningless, or (iii) communicative.

10.2.2.2 Guess responses

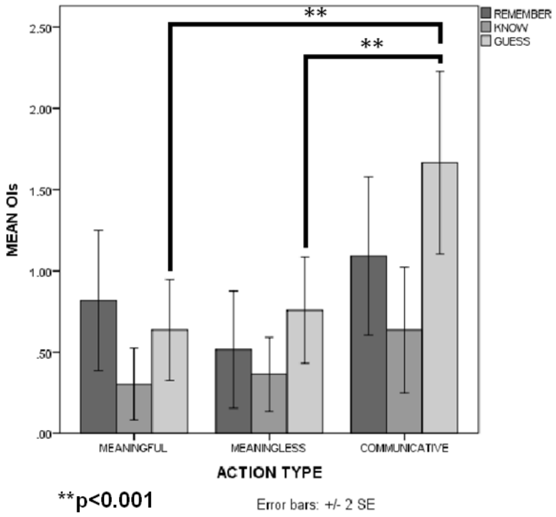
The 'Guess' responses indicate little, none or very low confidence in recalling the action (Dunn, 2004). In the previous experimental chapters, the 'Guess' response was omitted in the calculation of OI and SAI scores, as well as in the correct attributions of performed and observed actions. In this chapter, the 'Guess' responses will be analysed separately from the 'Remember' and 'Know' recollections. The 'Guess' responses will be compared across different action types (meaningful, meaningless and communicative) in each experimental chapter.

10.3. Results

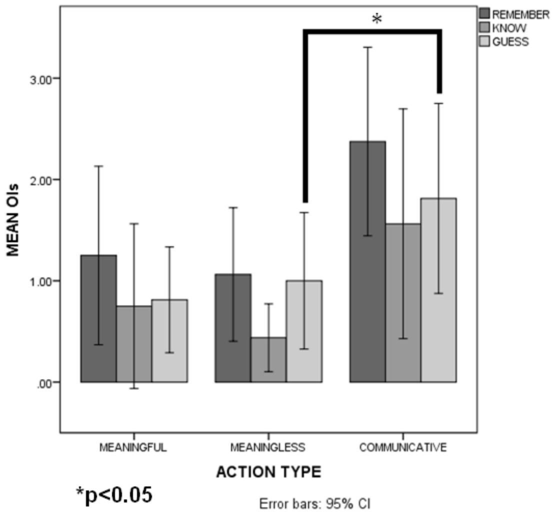
The aim of this study was to investigate the memory recollection types for OIs and SAIs, particularly how different types of actions (meaningful, meaningless and communicative) are recalled by participants. Participants' memories of action source were tested with the R-K-G questionnaire. Participants answered that they (i) 'Remembered, (ii) 'Knew' or (iii) 'Guessed' that they had incorrectly performed (OI) or incorrectly observed (SAI) actions. Below are the results of the analysis of participants' recollections from all experiments reported in this thesis.

10.3.1 Recollection of OIs

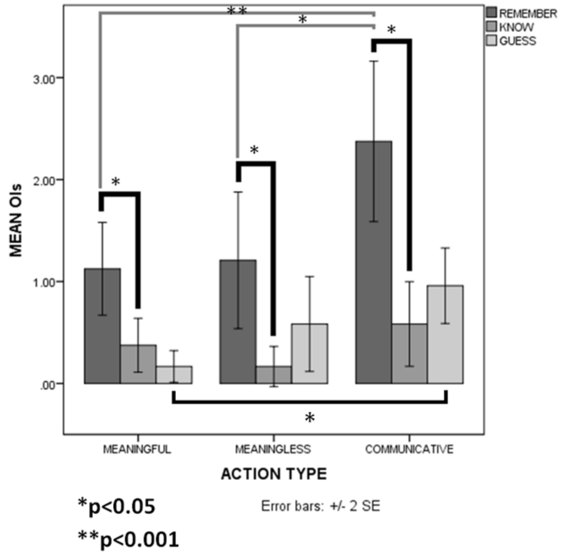
This section reports the recollection of OIs. See Figure 10.1 for OI. Significance is demonstrated with the significance stars. No stars indicates no significance.



Experiment 1, Chapter 6



Experiment 3, Chapter 8



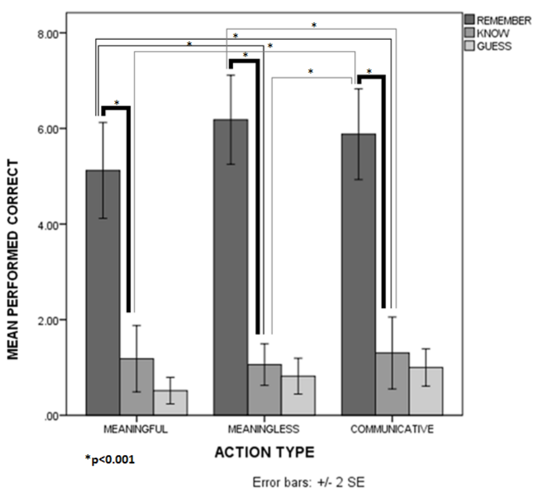
Experiment 4, Chapter 9 (just the OIs)

'The observation inflation effect – memory for different types of actions.'

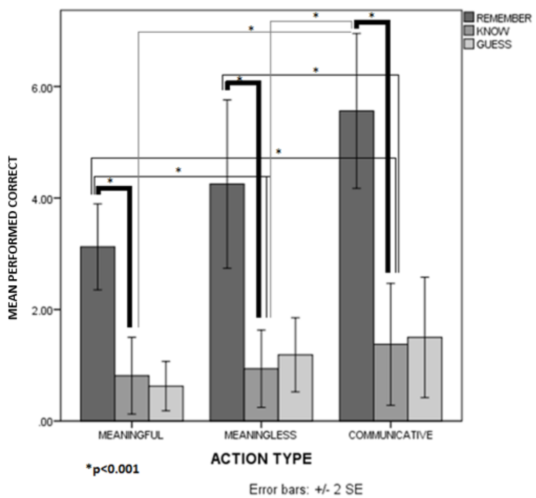
'Observation inflation in the cohort of elderly participants.'

'The role of instruction in the formation of observation and self-action inflations.'

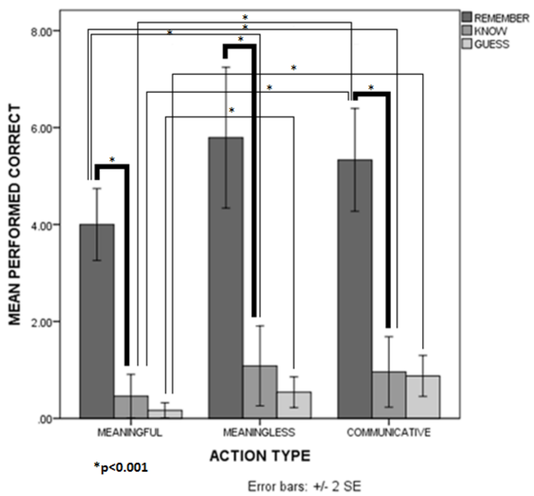
Figure 10.1 – Mean OIs for different types of actions, (i) meaningful, (ii) meaningless and (iii) communicative recalled with (i) 'Remember', (ii) 'Know' or (iii) 'Guess' in Experiment 1 (Chapter 6), Experiment 3 (Chapter 8) and Experiment 4 (Chapter 9).



Experiment 1, Chapter 6



Experiment 3, Chapter 8



Experiment 4, Chapter 9

'The observation inflation effect – memory for different types of actions.'

'Observation inflation in the cohort of elderly participants.'

'The role of instruction in the formation of observation and self-action inflations.'

Figure 10.2 – Mean correct source attributions of performed actions for different types of actions, (i) meaningful, (ii) meaningless and (iii) communicative recalled with (i) 'Remember', (ii) 'Know' or (iii) 'Guess' in Experiment 1 (Chapter 6), Experiment 3 (Chapter 8) and Experiment 4 (Chapter 9).

The assumption of normality has not been met for the sample conditions Standard parametrical tests were carried out alongside non-parametric test. For this section both analyses showed the same results. The parametric analysis is reported.

For each experiment, the results were analysed with a 3 x 2 repeated-measures ANOVA, where the independent variable was the action type (meaningful vs. meaningless vs. communicative) and the mean number of inflations formed for the two recollection types was the dependent variable ('Remember' vs. 'Know').

For the results of Experiment 1, Chapter 6, (‘The observation inflation effect – memory for different types of actions’) and Experiment 3, Chapter 8 (‘Observation inflation in the cohort of elderly participants’), there was no significant main effect of recollection type ($p>0.05$) and no significant interaction between the action type and recollection type, suggesting that different action types were equally likely to be recalled with either ‘Remember’ or ‘Know’.

However, the experiment of Chapter 9, the control experiment entitled ‘The role of instruction in the formation of observation and self-action inflations’, for the OI condition, showed a significant interaction between the recollection type and action type, $F(1, 46) = 3.39$, $p<0.05$, showing that inflations/errors for different types of actions were recalled differently with the ‘Remember’ and ‘Know’ recollections. See Figure 10.1. Post-hoc analysis with paired samples t-tests revealed that for all action types significantly more OIs were made with 'Remember' judgements as compared to 'Know' with (i) meaningful ($t(23) = 2.53$, $p <0.05$ (ii) meaningless ($t(23) = 2.87$, $p <0.05$ and (iii) communicative ($t(23) = 3.48$, $p<0.05$). See Figure 10.1. Furthermore, (i) significantly more communicative actions were recalled with ‘Remember’ responses than meaningless actions ($t(23) = -3.44$, $p<0.05$); (ii) significantly more communicative actions were recalled with ‘Remember’ responses than meaningful actions ($t(23) = 3.9$, $p = 0.001$). There was no significant difference between OIs recalled with the 'Remember' response between meaningful and meaningless actions ($p>0.05$) This shows that the communicative inflations as compared to meaningful and meaningless were of the strongest trace and participants were more likely to recall qualitative details associated with those actions. There was no significant difference found for 'know' responses for any action type.

10.3.1.1 Correct attribution of performed actions in OI experiments

For comparison of recollection type/confidence judgments of correct responses with those made for inflations (errors) made, formal analysis of the correct responses are now analysed. Non-parametric analysis is reported for the correct attribution of performed actions. For each experiment, the results were analysed with Friedman's tests and Wilcoxon signed ranks tests where the independent variable was the action type (meaningful vs. meaningless vs. communicative) and the mean number of correct attributions formed for the two recollection types was the dependent variable ('Remember' vs. 'Know'). Non-parametric analysis is reported in this section.

In Experiment 1 of Chapter 6 ('The observation inflation effect – memory for different types of actions') the analysis with Wilcoxon signed ranks test showed that significantly more correctly performed actions were recalled with 'Remember' than 'Know' responses overall, $Z = -4.35$, $p<0.001$. The analysis with Friedman's test showed that there was a significant difference in the number of different responses made for the three types of actions, $\chi^2(5) = 74.18$, $p<0.001$. Post hoc analysis with Wilcoxon signed-rank tests was conducted with Bonferroni correction applied, resulting in a significance level set at $p<0.003$. The results of Wilcoxon signed-rank tests revealed that significantly more correct actions were recalled with 'Remember' than 'Know' for meaningful actions ($Z = -3.78$, $p<0.001$), meaningless actions ($Z = -4.66$, $p<0.001$) and communicative actions ($Z = -3.76$, $p<0.001$). Additionally, it was found that significantly more meaningful actions were recalled as 'Remembered' than meaningless actions recalled with 'Know' ($Z = -4.33$, $p<0.001$) and communicative actions with 'Know' ($Z = -3.52$, $p<0.001$). Significantly more meaningless actions were recalled with 'Remember' than communicative actions with 'Know' ($Z = -4.02$, $p<0.001$). Additionally, significantly more communicative actions were recalled with 'Remember' than meaningful ($Z = -4.08$, $p<0.001$) and meaningless actions ($Z = -4.65$, $p<0.001$) with 'know' response.

Similarly in Experiment 3 of Chapter 8 ('Observation inflation in the cohort of elderly participants'), it was found that more 'Remember' than 'Know' recollections were made for the correctly attributed actions overall, $Z = -2.37$, $p<0.001$. The results of Friedman's test showed that there was a significant difference in the number of 'Remember' and 'Know' responses given for the three types of actions, $\chi^2(5) = 106.56$, $p<0.001$. Post hoc analysis with Wilcoxon signed-rank tests was conducted with Bonferroni correction applied, resulting in a significance level set at $p<0.003$. The analysis showed that significantly more 'Remember' than 'Know' responses were made for meaningful ($Z = -4.65$, $p<0.001$), meaningless ($Z = -5.42$, $p<0.001$) and communicative actions ($Z = -4.72$, $p<0.001$). Additionally, it was found that significantly more communicative actions were recalled with 'Remember' response than meaningful actions ($Z = -3.35$, $p<0.004$); significantly more meaningful actions were recalled with 'Remember' than meaningless actions with 'Know' ($Z = -5.08$, $p<0.001$) and communicative actions with 'Know' recollection ($Z = -3.98$, $p<0.001$). Significantly more meaningless actions were recalled with 'Remember' recollection than communicative actions with 'Know' recollection ($Z = -4.72$, $p<0.001$). Furthermore, it was found that significantly more 'Remember' recollections were made for communicative actions than 'Know' recollections for meaningful ($Z = -5.22$, $p<0.001$) and meaningless actions ($Z = --5.6$, $p<0.001$). This demonstrates that correct responses were remembered with high confidence and the participants were able to recall qualitative details associated with these actions.

Furthermore, a similar pattern was seen for the control experiment, Experiment 4 of Chapter 9 ('The role of instruction in the formation of observation and self-action inflations') where the questionnaire was designed to avoid bias. The results revealed that overall, significantly more 'Remember' than 'Know' recollections were made regardless of the action type, $Z = -3.8$, $p<0.001$. The analysis with Friedman's test revealed that there was a significant difference in the number of 'Remember' and 'Know' recollections formed for different types of actions, $\chi^2(5) = 65.68$, $p<0.001$. Post hoc analysis with Wilcoxon signed-rank tests was conducted with Bonferroni correction applied, resulting in a significance level set at $p<0.003$. The analysis showed that significantly more 'Remember' than 'Know' recollections were made for meaningful ($Z = -3.81$, $p<0.001$), meaningless ($Z = -3.6$, $p<0.001$) and communicative actions ($Z = -3.61$, $p<0.001$). Additionally, significantly more meaningful actions were recalled with 'Remember' than meaningless actions with 'Know' ($Z = -3.51$, $p<0.001$); significantly more meaningful actions were recalled with 'Remember' than communicative actions with 'Know' ($Z = -3.45$, $p=0.001$); significantly more communicative actions were recalled with ‘Remember’ than meaningful (Z = -3.97, p<0.001) and meaningless (Z = -3.53, p<0.001) actions with ‘Know’ recollection.

10.3.2 Recollection of SAIs

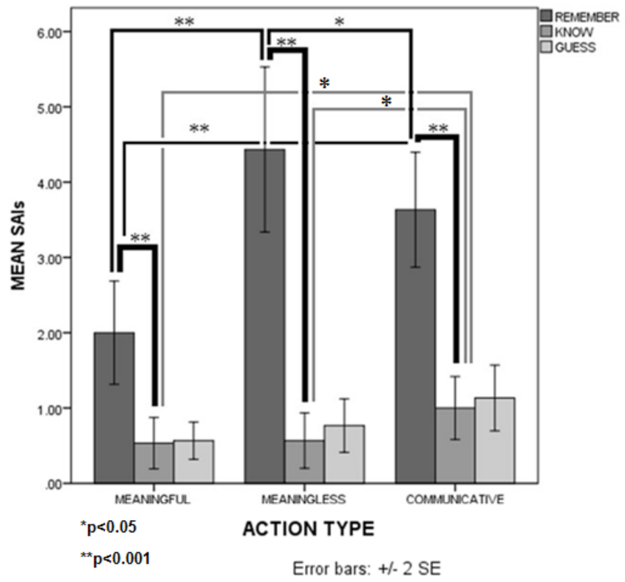
The pattern of R-K-G recollections for SAIs in Experiment 2 (Chapter 7) and Experiment 4 (Chapter 9) is analysed in this section. If mirror neurones are involved in the inflations, we expect a similar pattern of recollection judgements for SAIs; in particular for the control experiment, Experiment 4 (Chapter 9) where bias of the questionnaire was controlled for and where no significant difference was found between the number of OIs and SAIs made. See Figure 10.3 for SAIs and Figure 10.4 for the recollection for actions correctly recognised as observed. For each experiment, the results were analysed with a 3 x 2 repeated-measures ANOVA, where the independent variable was the action type (meaningful vs. meaningless vs. communicative) and the mean number of inflations formed for the two recollection types was the dependent variable ('Remember' vs. 'Know'). Parametric analysis is reported for in this section.

For the results of Experiment 4, Chapter 9 (‘The role of instruction in the formation of observation and self-action inflations’), there was no significant main effect of recollection type (p>0.05) and no significant interaction between the action type and recollection type, suggesting that different action types were equally likely to be recalled with either ‘Remember’ or ‘Know’. This was surprising given the results from the OIs of this control experiment. See Figure 10.1 and section 10.3.1 which shows and interaction between action type and recollection type with the communicative OIs remembered with more qualitative details (more 'Remember' responses as compared to meaningful and meaningless actions).

However, the results of Experiment 2, Chapter 7 (‘Self-action inflation - misattribution of self-performed actions as observed’) showed that there was a significant main effect of recollection type, $F(1, 29) = 36.45$, $p<0.001$. Pairwise-comparisons revealed that significantly more ‘Remember’ recollections were made than ‘Know’ recollections (p<0.05) overall.

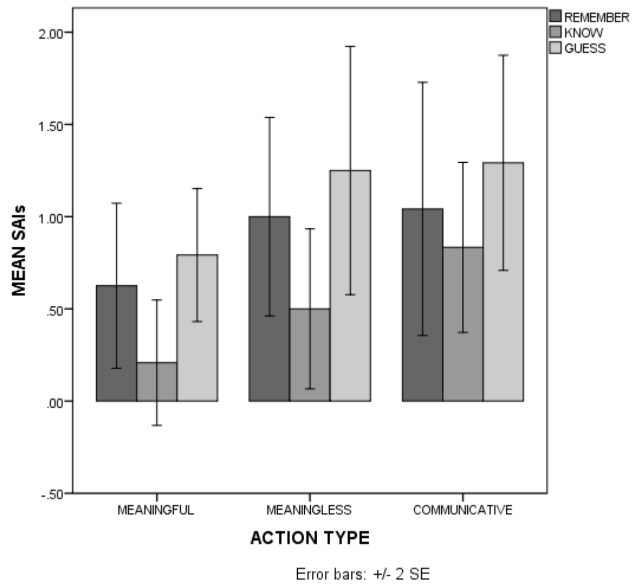
The results of Experiment 2 also revealed that there was a significant interaction between SAI for action type and recollection type, $F(2, 58) = 21.81$, $p<0.001$, suggesting that there was a significant difference in the recollections participants had for the three action types.

Post-hoc analysis with paired-samples t-tests revealed that SAIs for all action types were recalled, although incorrectly, with significantly more 'Remember' responses than 'Know' responses with (i) meaningful ($t(29) = 3.74$, $p<0.001$); (ii) meaningless actions with ($t(29) = 6.53$, $p<0.001$) and (iii) communicative actions with ($t(29) = 5.77$, $p<0.001$). Furthermore, (i) significantly more SAIs for meaningless actions were recalled as 'Remembered' than meaningful actions ($t(29) =-6.74$, $p<0.001$); (ii) significantly more SAIs for meaningless actions were recalled as 'Remembered' than communicative actions ($t(29) =2.08$, $p<0.05$); (iii) significantly more SAIs for communicative actions were recalled as 'Remembered' than meaningful actions ($t(29) =7.92$. $p<0.001$); (iv) significantly more meaningless actions were recalled as 'Known' than communicative actions ($t(29) = -2.76$, $p<0.05$) and (v) significantly more communicative actions were recalled as 'Known' than meaningful actions ($t(29) = 2.84$, $p<0.05$.



Experiment 2, Chapter 7

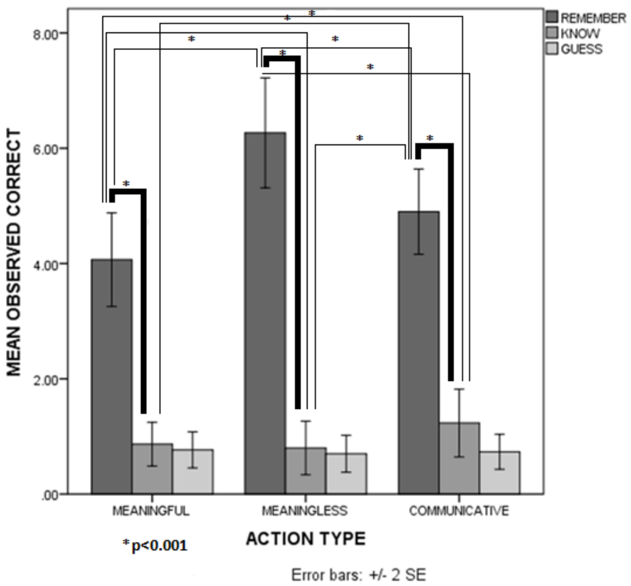
‘Self-action inflation - misattribution of self-performed actions as observed.’

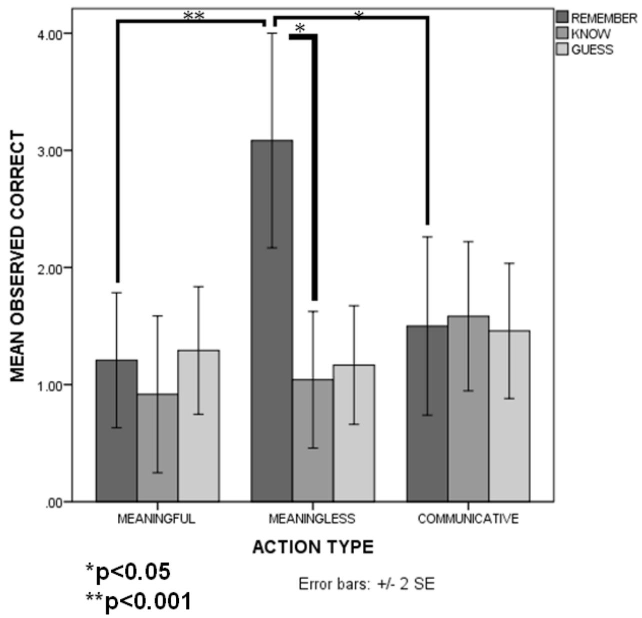


Experiment 4, Chapter 9

‘The role of instruction in the formation of observation and self-action inflations.’

Figure 10.3 – Mean SAIs for different types of actions, (i) meaningful, (ii) meaningless and (iii) communicative recalled with (i) 'Remember', (ii) 'Know' or (iii) 'Guess' in Experiment 2 (Chapter 7), Experiment 4 (Chapter 9).





Experiment 2, Chapter 7

'Self-action inflation - misattribution of self-performed actions as observed.'

Experiment 4, Chapter 9

'The role of instruction in the formation of observation and self-action inflations.'

Figure 10.4 – Mean SAIs for different types of actions, (i) meaningful, (ii) meaningless and (iii) communicative recalled with (i) 'Remember', (ii) 'Know' or (iii) 'Guess' in Experiment 2 (Chapter 7), Experiment 4 (Chapter 9).

10.3.2.1 Correct attribution of observed actions in SAI experiments

To investigate recollection types for errors (SAIs) and correct responses, for each experiment, the results were analysed with Wilcoxon signed ranks tests and Friedman's tests, where the independent variable was the action type (meaningful vs. meaningless vs. communicative) and the mean number of correct attributions formed for the two recollection types was the dependent variable ('Remember' vs. 'Know'). Non-parametric analysis is reported in this section.

Results of Experiment 2, Chapter 7 ('Self-action inflation - misattribution of self-performed actions as observed') revealed that significantly more 'Remember' than 'Know' recollections were made overall, $Z = -4.65$, $p<0.001$. Further analysis with Freidman's test showed that there was a significant difference in the number of 'Remember' and 'Know' recollections for the three different types of actions, $\chi^2(5) = 83.84$, $p<0.001$. Post hoc analysis with Wilcoxon signed-rank tests was conducted with Bonferroni correction applied, resulting in a significance level set at $p<0.003$. The analysis revealed that (i) significantly more meaningful actions were correctly recalled with 'Remember' than 'Know' ($Z = -4.37$, $p<0.001$); (ii) significantly more meaningless actions were recalled with 'Remember' than 'Know' ($Z = -4.56$, $p<0.001$); (iii) significantly more communicative actions were recalled with 'Remember' than 'Know' ($Z = -4.06$, $p<0.001$). Furthermore, (i) significantly more meaningless actions were recalled as 'Remembered' than meaningful actions ($Z = -4.14$, $p<0.001$); (ii) significantly more meaningless actions were recalled as 'Remembered' than communicative actions ($Z = -4.45$, $p<0.001$); (iii) significantly more meaningful actions were recalled with 'Remember' recollection than meaningless with 'Know' ($Z = -4.42$, $p<0.001$) and (iv) communicative with 'Know' ($Z = -3.8$, $p<0.001$); (v) significantly more meaningless actions were recalled with 'Remember' than communicative actions with 'Know' ($Z = -4.42$); (vi) significantly more communicative actions were recalled with 'Remember' than meaningful actions with 'Know' ($Z = -4.45$, $p<0.001$) and (vii) meaningless actions with 'Know' ($Z = -4.6$, $p<0.001$).

For the results of Experiment 4, Chapter 9 ('The role of instruction in the formation of observation and self-action inflations'), there was a significant difference in the number of ‘Remember’ and ‘Know’ recollections made overall, where significantly more SAIs were recalled with ‘Remember’ recollection, $Z = -2.2$, $p<0.05$. Further analysis with Freidman’s test revealed that there was a significant difference in the number of ‘Remember’ and ‘Know’ recollections formed for the three types of actions, $\chi^2(5) = 23.29$, $p<0.001$. Post hoc analysis with Wilcoxon signed-rank tests was conducted with Bonferroni correction applied, resulting in a significance level set at $p<0.003$. The results showed that there was significantly more ‘Remember’ recollections were made for meaningless than meaningful actions ($Z = -3.47$, $p=0.001$).

10.3.3 Summary of the results so far (OIs and SAIs)

The results revealed that the OIs were equally recalled with either ‘Remember’ or ‘Know’ in Experiment 1 (Chapter 6) and Experiment 3 (Chapter 8). However, in the control Experiment 4 (Chapter, 9) all action types were recalled with significantly more ‘Remember’ than ‘Know’ recollections suggesting a strong memory trace when misattributing observed actions as self-performed. This pattern was only found in Experiment 4 when possible questionnaire bias was controlled for. Here, when participants had to differentiate for themselves between the sources of their memory, they clearly made stronger recollections with ‘Remember’ for OIs. Additionally, the control experiment, Experiment 4 revealed a significant interaction between action and recollection types, showing that all action types were recalled with more ‘Remember’ than ‘Know’ recollections. ***Importantly, communicative actions were recalled with significantly more ‘Remember’ recollections than meaningful and meaningless actions.*** Regarding correct source attributions of self-performed actions, significantly more actions were recalled with ‘Remember’ than ‘Know’ recollections for all experiments.

Regarding SAIs, all action types were similarly recalled with either ‘Remember’ or ‘Know’ in Experiment 4 (Chapter 9). However, in Experiment 2 (Chapter 7), all action types were recalled with significantly more ‘Remember’ than ‘Know’ recollection. Additionally, significantly more meaningless actions were recalled with ‘Remember’ than meaningful and communicative actions. More communicative actions were recalled with a 'Remember' recollection than meaningful actions.

As for the correct attribution of observed actions, significantly more actions were correctly recalled as 'Remembered' rather than 'Known' in all action type conditions in Experiment 2 (Chapter 7) and in Experiment 4 (Chapter 9).

10.3.4 'Guess' recollections for OI experiments

This section reports the 'Guess' recollection in OIs experiments. See Figure 10.1. For each experiment, the results were analysed with a repeated-measures ANOVA, where the independent variable had three levels which was the action type (meaningful vs. meaningless vs. communicative). The dependent variable was the mean numbers of responses made with a 'Guess' recollection. Parametric analysis is reported in this section.

The results revealed that there was a significant main effect of action type for , Experiment 1 of Chapter 6 ('The observation inflation effect – memory for different types of actions') $F(2, 64) = 12.94$, $p<0.001$, Experiment 3, Chapter 8 ('Observation inflation in the cohort of elderly participants') $F(2, 30) = 3.31$, $p=0.05$ and Experiment 4, Chapter 8 ('The role of instruction in the formation of observation and self-action inflations.') $F(2, 46) = 6.38$, $p<0.05$. For Experiment 1, pairwise-comparisons revealed that significantly more communicative actions were recalled with 'Guess' than meaningful ($p=0.001$) and meaningless actions ($p=0.001$) in. For Experiment 3, pairwise-comparisons revealed that significantly more communicative than meaningful actions were recalled with 'Guess' ($p<0.05$). There was no significant difference found between communicative and meaningless actions ($p>0.05$) and meaningful and meaningless actions ($p>0.05$). For the control experiment, Experiment 4, pairwise-comparisons showed that significantly more communicative actions were recalled with 'Guess' than meaningful actions ($p<0.05$). There was no significant difference in 'Guess' responses between communicative and meaningless actions ($p>0.05$) and meaningful and meaningless actions ($p>0.05$).

10.3.4.1 ‘Guess’ recollections of self-performed actions in OI experiments

This section reports the ‘Guess’ recollections of self-performed actions in the OI experiments. See Figure 10.2. The non-parametric analysis is reported. For each experiment, the results were analysed with Wilcoxon signed rank tests, where the independent variable had three levels which was the action type (meaningful vs. meaningless vs. communicative). The dependent variable was the mean numbers of responses made with a ‘Guess’ recollection. Non-parametric analysis is reported in this section.

There was no significant difference ($p>0.05$) in the number of ‘Guess’ recollections formed between the three types of actions in Experiment 3, Chapter 8 (‘Observation inflation in the cohort of elderly participants’).

However the results of Experiment 1, Chapter 6 (‘The observation inflation effect – memory for different types of actions’), revealed that there was a significant difference in the number of ‘Guess’ recollections formed between meaningful and communicative actions ($Z = -2.11$, $p<0.05$), suggesting that significantly more ‘Guess’ responses were made for communicative than meaningful actions. In the Experiment 4, Chapter 9 (‘The role of instruction in the formation of observation and self-action inflations’), the analysis with Wilcoxon signed ranks test revealed that (i) significantly more meaningless actions were ‘Guessed’ than meaningful actions and (ii) significantly more ‘Guess’ recollections were formed for communicative than meaningful actions.

10.3.5 ‘Guess’ recollections for the SAI experiments

This section reports the ‘Guess’ recollection in SAIs experiments. The same as with OIs, for each SAI experiment, the results were analysed with a repeated-measures ANOVA, where the independent variable had three levels which was the action type (meaningful vs. meaningless vs. communicative). The dependent variable was the mean numbers of responses made with a ‘Guess’ recollection. Parametric analysis is reported in this section.

There was no significant main effect of action type in Experiment 4, Chapter 9 ('The role of instruction in the formation of observation and self-action inflations'), suggesting that all action types were equally recalled with 'Guess' recollection.

However in Experiment 2 of Chapter 7 ('Self-action inflation - misattribution of self-performed actions as observed'), the results revealed a significant main effect of action type, $F(2, 59) = 4.18$, $p<0.05$. Pairwise-comparisons showed that significantly more communicative actions were recalled as 'Guessed' than meaningful actions ($p<0.05$). There was no significant difference found in the 'Guess' recollections between communicative and meaningless actions ($p>0.05$); and meaningful and meaningless actions ($p>0.05$).

10.3.5.1 'Guess' recollections for observed actions in SAI experiments

This section reports the 'Guess' recollection for correctly recalled observed actions in SAIs experiments. The same as with SAIs experiments, the results were analysed with a repeated-measures ANOVA, where the independent variable had three levels which was the action type (meaningful vs. meaningless vs. communicative). The dependent variable was the mean numbers of responses made with a 'Guess' recollection.

The results of Experiment 2, Chapter 7 ('Self-action inflation - misattribution of self-performed actions as observed') and Experiment 4 of Chapter 9 ('The role of instruction in the formation of observation and self-action inflations'), revealed that there was no significant main effect of action type ($p>0.05$) suggesting that different action types were equally recalled with the 'Guess' recollection in these experiments.

10.3.6 False memory

In addition to recollective experience of OIs and SAIs, the current Chapter examines the formation of false memories reported in the experimental chapters in this thesis. These were statements written on the questionnaire in the test phase that had neither been performed nor observed in the study phase.

10.3.6.1 False memories of self-performance

The false memories of self-performance are when participant neither observed nor performed the actions in the experiments but indicated in the source memory questionnaire that they had performed them. The false statements were included in Experiment 1, Chapter 6 ('The observation inflation effect – memory for different types of actions'), Experiment 3, Chapter 8 ('Observation inflation in the cohort of elderly participants') and Experiment 4, Chapter 9 ('The role of instruction in the formation of observation and self-action inflations'). Parametric analysis is reported in this section.

Figure 10.5 shows that the highest number of false memories was formed in the elderly cohort in Experiment 3 (Chapter 8). Almost the same number of false memories was formed in OI experiments of Chapters 6 and 9.

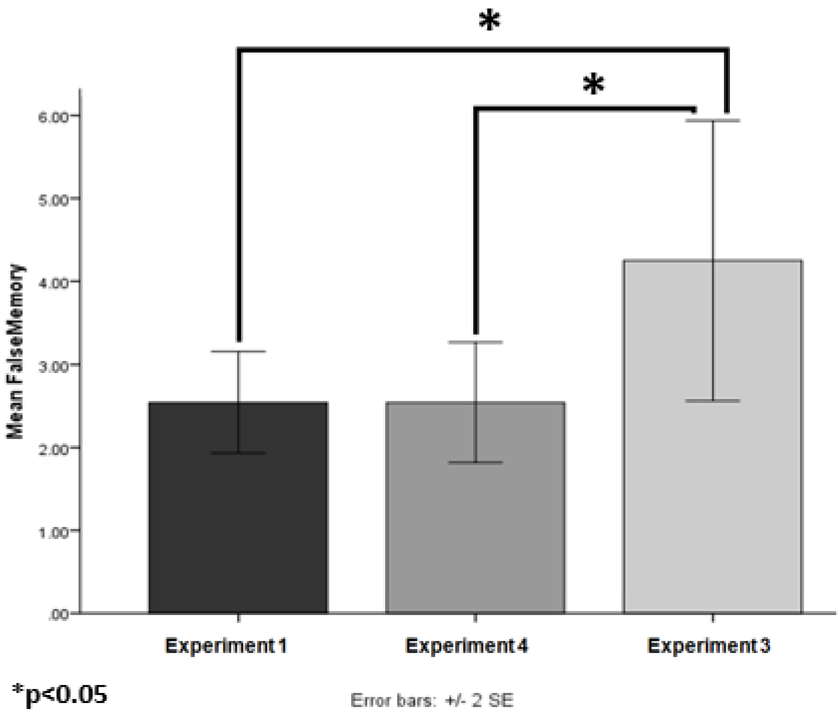


Figure 10.5 – Mean and standard errors for false memories formed in Experiment 1 (Chapter 3), Experiment 3 (Chapter 8) and Experiment 4 (false memories of self-performance only).

This was analysed with an independent samples t-tests which revealed that there was; (i) a significant difference in the number of false memories formed between the inflations made by the young participants in Experiment 1 and the elderly participants in Experiment 3, $t(49) = 2.36$, $p<0.05$, where more false memories where formed in Experiment 3 by elderly participants (Chapter 8); (ii) unsurprisingly a significant difference in the number of false memories formed in the elderly cohort of Experiment 3 and the young participants in Experiment 4, $t(38) = 2.09$, $p<0.05$). Elderly participants in Experiment 3 formed more false memories than young participants in Experiment 4; (iii) no significant difference was found in the false memories formed between Experiments 1 and 4 ($p>0.05$). This is interesting as it seems to imply that the controlled nature of the questionnaire had no effect on the false memories formed in Experiment 4.

10.3.6.2 False memories of observation of actions

The false memories of observation are when participants recalled observing another person performing an action when in fact they neither observed the action nor performed the action themselves.

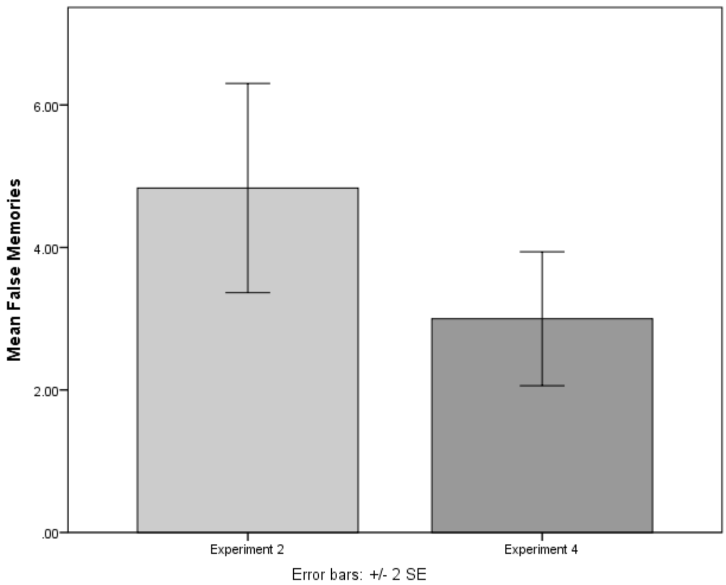


Figure 10.6 - Mean and standard errors for false memories formed in Experiment 2 (Chapter 7) and Experiment 4 (false memories of self-performance only).

This was analysed with an independent-samples t-test which showed that there was no significant difference between the number of false memories formed in Experiment 2 and Experiment 4 ($p>0.05$). This means participants were equally likely to recall observing someone performing actions in the video presentation, when in fact they did not observe the actions, neither had they performed it and the wording of the questionnaire had no influence on the results.

10.3.6.3 Comparison between false memories of action observation and self-performance

The false memories of self-performance from Experiment 1 (Chapter 6), Experiment 3 (Chapter 8) and Experiment 4 (Chapter 9) and action observation from Experiment 2 (Chapter 7) and Experiment 4 (Chapter 9) were summed to create a total error variable of two false memories types.

The total false memories of self-performance and false memories of action observation were compared with independent-samples t-test which showed that overall, participants were equally likely to form false memories of either self-performance or observation of action performance ($p>0.05$).

10.4 Discussion

10.4.1 Summary of results

The recollective pattern of OIs and SAIs was investigated in the current study along with the results for the correct source attribution. Overall, the observed actions were equally likely to be recalled with ‘Remember’ and ‘Know’ recollection as self-performed in Experiments 1 and 3. Significantly more actions were recalled as ‘Remembered’ than ‘Known’ in all action type conditions in the control experiment, Experiment 4. Additionally, significantly more communicative actions were recalled as ‘Remembered’ than meaningful and meaningless actions in Experiment 4. The **correct attribution** of performed actions was the highest with ‘Remember’ recollections in all experiments. The high rate of ‘Remember’ responses may possibly suggest strong level of confidence about performing these actions. This shows that the OIs formed and retrieved as ‘Remembered’ shared a similar level of detail as the actions that were actually performed. The recollective pattern of OIs did not differ between young and elderly participants, showing that the actions were recollected at the same rate between the two groups. Interestingly and importantly this interaction effect was only seen for the inflations and not in the correct responses.

The SAI errors were also more likely to be recalled as 'Remembered' in Experiment 2 (Chapter 7) suggesting high qualitative detail of misattributions formed, which might have been due to the fact that participants had actually performed the actions, thus leaving a stronger memory trace. It is unclear why a different pattern of recollection was found in the control study (Experiment 4), where the actions were equally recalled with different recollection types. This is surprising, since the OI recollection in the same experiments resulted in significantly more 'Remember' recollection than 'Know' recollections and the questionnaire in Experiment 4 was well controlled for. This is problematic for the mirror neurone hypothesis as it would be predicted that both types of error would be formed with similar strategies so needs further investigation.

The 'Guess' recollections for OIs, SAIs and both correct recollections of observed and performed actions showed that significantly more communicative actions were recalled as 'Guessed' than meaningful actions. This may suggest less detailed and less confident memory in general for communicative actions when unsure.

In the case of false memories, it was found that elderly participants (Experiment 3, Chapter 8) formed significantly more false memories than younger participants (Experiments 1, 2 and 4). Participants were equally likely to form false memories of either self-performance or action observation.

10.4.1 Discussion of the OI results

This chapter aimed to investigate the 'Remember', 'Know' and 'Guess' recollection types for OIs and SAIs across the data from all experiments in the thesis.

The results indicate that in Experiment 1 and Experiment 3, observed actions were recalled similarly with either ‘Remember’ or ‘Know’ responses. This is in agreement with the results of Manzi and Nigro’s (2008) study which also found that observed actions are equally likely to be recalled as performed with either ‘Remember’ or ‘Know’ responses. The results of Experiment 4 are not in line with Manzi and Nigro’s findings, since it was found that all action types were recalled with significantly more ‘Remember’ than ‘Know’ responses. Although Experiment 4 used a similar source differentiation procedure in the source memory questionnaire as Manzi and Nigro (2008), methodological differences such as different action types used in Experiment 4 as opposed to only meaningful actions in Manzi and Nigro’s (2008) study could have contributed to a different pattern of recollection in the two studies, in particular the interaction effect which showed that more communicative actions were recalled with a 'Remember' response.

As for the recollective experience in the elderly cohort in Experiment 3, the actions were equally likely to be recalled with either ‘Remember’, ‘Know’. This finding is not line with previous research on recollection in the elderly, which suggests that elderly tend to make more ‘Remember’ recollections than ‘Know’ or ‘Guess’ recollections (Aizpurua et al., 2009). Additionally, it has been shown that the elderly make more ‘Remember’ responses when compared to younger participants (Aizpurua et al., 2009), which again is not supported by the results of this study, as it has been found that there was no significant difference in the recollections participants formed between the elderly and young participants group. It is unclear why the elderly did not form more ‘Remember’ recollections. One of the explanations could be that they simply did not remember the actions due to age related memory decline and recalled some of the actions with a ‘Guess’ response.

Interestingly, in the Experiment 4, where the bias in the questionnaire was controlled for, all action types were recalled with significantly more ‘Remember’ than ‘Know’ responses and an interaction between action type and recollection was found which showed that communicative actions were recalled with significantly more ‘Remember’ responses than meaningful and meaningless actions. The interaction between the action type and recollection was not found in either Experiment 1 or 3. The high recollection rate with ‘Remember’ suggests that participants formed detailed misattributions of the observed actions as self-performed. This result further supports that the questionnaire from Experiment 4 was a better method of investigating the memory errors, and eliminated the questionnaire bias present in Experiment 1 and 3.

Importantly for the investigation of mirror neurone involvement, the controlled methodology of Experiment 4 showed that observation of communicative actions rather than meaningful and meaningless actions, resulted in significantly more recollections of self-performance with ‘Remember’. The possible and hypothesised increase in mirror neurone activity during observation of communicative actions could lead to heightened misattribution levels because of shared neural activation between observation and performance (Husain et al. 2012; Andric et al., 2013). This could explain why significantly more communicative actions resulted in OIs of self-performance with a strong, detailed memory trace and high confidence. One potential explanation which would need further investigation could be that the lack of distinguishable features in the case of communicative actions (no objects present), might lead to a higher number of misattributions, as the action is familiar to the individual but lacks the detail that would allow for discrimination between self and observed performance.

Comparing it to correct source attributions of actions that were actually performed which were predominately recollected as ‘Remembered’, the results show that the recollective experience of OIs is similarly detailed as memories of actual action execution. The high rate of performed actions correctly attributed to their source with a ‘Remember’ recollection type in all OI experiments hints at strong and detailed memory for these actions. Unsurprisingly as this effect has been widely demonstrated in cognitive research and has been termed the ‘self-reference recollective effect’ (SRRE). SRRE shows that self-reference during encoding of memory results in advantages in further retrieval of that memory (Conway and Dewhurst, 1995). However the interaction of confidence judgement and action type was only significant for the inflations, i.e. the errors.

10.4.2 Discussion of SAIs results

As for the SAIs in Experiment 2, the highest number of all errors was recollected as 'Remembered'. This suggests detailed memories of self-performance misremembered as performed by somebody else. Similarly as in the case of OIs, it could potentially be a consequence of mirror neurone activity, with the sources of actions being confused between performance and observation. The actions were recollected as 'Remembered' because the execution left a strong memory trace for the action. The source confusion might have occurred because of familiarity with the actions (meaningful and communicative), and also distinctiveness of meaningless actions and seemingly having higher plausibility to have been performed by somebody else (especially in Experiment 2, where most of the misattributions were for meaningless actions) (Rumiati and Tessari, 2002). The same pattern was seen for correct responses, showing that for memory errors and correct responses, 'Remember' and 'Know' judgements of the actions were similar. This suggests that it is part of the recollection and the wording of the questionnaire interfering with the confidence judgments of the participants with quite a strikingly number of high confidence judgements made for meaningless actions (both for correct responses and SAIs).

However, in the control condition (Experiment 4), no significant difference was found between the different recollection types, nor was there a significant interaction between the recollection and action types. This suggests that all action types were similarly recalled with different recollections. This result is different from the pattern of recollections of OIs in the same experiment, which showed a significant interaction between the action and recollection types. This is a surprising result, and potentially problematic for the mirror neurone hypothesis as it was expected, because of the wording of the questionnaire being controlled for in this experiment, that the recollective pattern for OIs and SAIs should be similar, especially given that the number of OIs and SAIs formed overall (R+K totalled) showed no difference. Importantly and interestingly, the same pattern was seen for the correct responses i.e. interaction between recollection and action type as was seen for the inflations. For the OI experiments, a significant interaction was seen only for the inflations in this control experiment and not for the correct responses showing that an effect was only apparent when a memory error occurred.

It was also found that the false memories recorded in the OI experiments, were significantly higher in the elderly cohort (Experiment 3, Chapter 8) than young adult participants (Experiments 1 (Chapter 6) and 4 (Chapter 9)). This is in line with previous research on false memories and ageing, which generally indicates higher susceptibility to formation of memory errors and source monitoring errors as age increases (e.g. Jacoby and Rhodes, 2006; Jacoby et al., 2012). As memory accuracy decreases with age, the available information (e.g. false statement in a questionnaire) may be misattributed as a real memory (Jacoby, 1999). This has potential implications for AD patients and healthy ageing.

10.4.3 Conclusions and future research

As far as I am aware, this is the first study to look at any possible role of mirror neurones in the memory recollection with the R-K-G paradigm. Since the current study investigated it behaviourally only, future research should examine neural underlying retrieval with R-K-G recollections for different types of actions. The main finding is that in the controlled experiment, Experiment 4, significantly more OIs for communicative actions were recalled with a 'Remember' response compared to the other action types. The results highlight the importance of studying SAIs in comparison to OIs as the results of the control study (OI and SAI) of Experiment 4 failed to concur, which was unexpected. Further paradigms should be created to test mirror neurones and R-K-G for instance in the context of in-group vs. outgroup setting (see Chapter 11) and by implementing neuroimaging. Neuroimaging is commonly used in investigating both mirror neurones and the RKG paradigm although to date, as far as I am aware, no neuroimaging studies have looked at these two together.

10.5 Highlights

- R-K-G allows study of different types of memory recollections.

- 'Remember' recollections indicate detailed memories and a sense of 'reliving' particular event.
- 'Know' responses are associated with feeling of familiarity.
- 'Guess' indicates little to no recollection.
- R-K-G was used to study the misattributions of actions performed by other people (OIs) and self-performed actions (SAIs).
- The analysis of OI recollection in Experiments 1 (Chapter 6) and 3 (Chapter 8) suggests that OIs were equally likely to be misattributed as ‘Remembered’ or ‘Known’.
- Significantly more meaningful, meaningless and communicative actions were recalled as ‘Remembered’ than ‘Known’ in Experiment 4 (Chapter 9).
- Significantly more communicative actions were recalled with ‘Remember’ response than meaningful and meaningless actions in Experiment 4 (Chapter 9).
- Elderly participants were equally likely to recollect actions with either ‘Remember’, ‘Know’ or ‘Guess’ (Experiment 4, Chapter 9).
- No significant difference was found in the pattern of recollection between young and elderly participants (Experiments 1 and 4).
- In Experiment 4, observation of all action types resulted in significantly more ‘Remember’ recollections as self-performed than ‘Know’ and ‘Guess’ recollections.
- This supports that the questionnaire in Experiment 4 might be a more efficient tool to test OI and SAI.
- Self-performed actions correctly attributed to their source were more likely to be recollected as ‘Remembered’ than 'Known' or 'Guessed' to have had been performed in Experiment, 1, 3 and 4.
- SAIs were more likely to be ‘Remembered’ than 'Known' or 'Guessed' in Experiments 2 and 3.
- Elderly participants formed more false memories than young participants.
- The results suggest that participants overall formed detailed recollections of actions that they misattributed to a wrong source.

- Correct attributions were more likely to be recollected as 'Remember' which may suggests a similarly detailed memory between the correct source attributions and misattributions of actions.
- Significantly more ‘Remember’ recollections of OIs for communicative than meaningful and meaningless actions in Experiment 4 suggests it is a better method of studying OIs.
- Future research should investigate the neural processes underlying R-K-G retrieval for different action types.

Chapter 11

The social aspect of observation inflations. Misattributing the actions of in-group and out-group actors

11.1 Introduction

In the previous chapters of this thesis, it was demonstrated that both observation and execution of actions can results in SMEs, where the observed actions are either misattributed as self-performed (Experiment 1, Experiment 3 and Experiment 4) or self-performed actions are falsely remembered to have been performed by other people (Experiment 2 and Experiment 4). These results supported the speculative hypothesis of mirror neurone involvement in the OI and SAI effects, showing that observation of both meaningful and communicative actions results in more OIs and SAIs than meaningless actions (Experiments, 1, 3 and 4). Although this was only partially demonstrated in Experiment 2, where a high number of SAIs was found to have been formed following execution of meaningless actions, this was possibly due to the wording of the questionnaire biasing the results. However, this was resolved in Experiment 4, where the questionnaire bias was controlled for. The results of Experiment 4 showed a similar pattern of OI and SAI formation, where significantly more communicative actions resulted in error formation than meaningful and meaningless actions.

The possible involvement of mirror neurones in the OI effect will now be investigated further in this thesis. Past research on mirror neurones and race has shown that the brain activity can be modulated by the race of an individual that one is observing.

For example, Gutsell and Inzlicht (2010) studied the mu suppression in the motor cortex during action observation of in-group (Caucasian) and out-group (East Asian, South Asian and African) actors. The actors performed a simple action of drinking from a glass of water which was presented to the participants in a video presentation. Gutsell and Inzlicht (2010) found that participants showed activity in the motor cortex when (i) they performed the action themselves and (ii) observed individuals belonging to the same ethnic group as themselves (in-group condition) but not when they observed members of other races perform the actions (out-group condition). Gutsell and Inzlicht (2010) suggested that mirror neurones might not be active to the same extent for individuals belonging to a different race. However, it is not clear whether it is a natural predisposition to exhibit a weak neural stimulation for members of out-group, but the prejudice towards these groups that causes the lower stimulation (Gutsell and Inzlicht, 2010).

Similar findings were demonstrated in imitation research. For example, Losin et al. (2012) showed that participants exhibited different neural activity when they imitated actions of individuals belonging to the same racial background as themselves (European American) compared to when they observed individuals of different races (African American and Chinese American). In the fMRI experiment, participants either (i) observed and imitated actions of the three actors; (ii) passively observed the action execution; or (iii) observed still photographs of the actors' faces. The actions performed by participants were derived from New Zealand Sign Language and were considered as meaningless to both actors and participants. Losin et al. (2012) found that the frontal, parietal and occipital brain areas were activated to a different extent when imitating actions of individuals of different races.

Avenati et al. (2010) showed that the perceived race of individual modulates the empathetic responses to the individual's pain. In a TMS study, participants observed videos of three different types of hands that showed induced pain with a needle. These were (i) a white individual's hand; (ii) a black individual's hand and (iii) a purple gloved hand. The results showed that observing an individual of the same race group being inflicted pain activated the corticospinal system to the same extent as if they were experiencing the pain themselves. This effect was present for both black and white individuals. A similar activity was registered when both black and white individuals observed the unfamiliar purple gloved hand. However, when the individuals observed the opposite race, no such activity was present. The authors suggest that the difference in empathetic reaction is not due to the unfamiliarity of the opposite race, as the same reaction would be exhibited for the unfamiliar purple glove. Rather, Avenati et al. (2010) suggest prejudice towards races as a factor contributing to the implicit empathetic responses.

Different results were found by Desy and Lepage (2013), however, who showed that imitation is not affected by racial prejudice. In an EEG experiment, Caucasian participants performed a simple imitation task in which they observed finger lifting and tapping movements performed by either a hand of either the black or white race. The results showed that neither RT for imitation of both types of hands nor the mu suppression exhibited any difference between the races. This suggests that the differences in neural processing for other races found in different studies are a product of cultural aspects not solely a physical dissimilarity (Desy and Lepage, 2013).

The aspect of race in the context of OIs has been previously research in, as far as I am aware, only one study by Lindner et al. (2012). The social conditions of the OI effect were investigated in an experiment where participants (N = 58) were required to perform and observe 20 actions in each condition. The observed actions were performed by either a (i) white female actor, (ii) dark skinned Sri-Lankan female actor or (iii) an actor wearing black gloves concealing the skin colour (Lindner et al., 2012). The videos only depicted the actor’s torso and hands. A two-week testing time delay was administered after which the participants filled in a source memory test where they specified which actions they performed themselves. The results revealed that the OI effect was significantly lower for the actions that were performed by the out-group actor i.e. more OIs were made when the actions were performed by the in-group actor which is the actor of the same race as the participant. Interestingly, this was not observed for the black gloved hands, suggesting individual’s group memberships has a stronger effect on processing of actions of others than physical characteristics only (Lindner et al., 2012). These results are thought to support the mirror neurone hypothesis of Linder et al., (2010) as there is more overlapping neural activity in the brain during the observation of the same race (Gutsel and Inzlicht, 2010). Thus, the similar brain activity could lead to more misattributions of the observed actions.

11.1.1 Aim of the current study

The current study will investigate the social aspect of the OI effect. Since the mirror neurone and imitation literature shows that observation of different races results in different neural processing, it is logically plausible to assume that this would affect the source memory for those actions as well. This was shown in the study by Lindner et al. (2012), where the OI effect was reduced following the observation of out-group individuals, supporting the mirror neurone hypothesis proposed by Linder et al. (2010). The current study will investigate this further not only in the context of the actor's race but also the type of action that is being performed. Thus, communicative actions (which were associated with highest rate of OIs formation in the experiment of this thesis) and meaningless actions (which resulted in the lowest mean OIs) will be used in this study. Based on the previous findings of experiments in this thesis, it will be hypothesised that observation of communicative actions will result in significantly more OIs than observation of meaningless actions. Furthermore, it is expected that the number of OIs will be higher in the in-group condition than out-group condition due to overlapping activation. This study was carried out at the International School for Advanced Studies (SISSA), Trieste, Italy in the Neuroscience and Society Lab.

11.2 Method

11.2.1 Participants

Eighty-four participants took part in the study. The participants were recruited from the Twins Italian Database (Registro Nazionale Gemelli) (mean age = 22.76, SD = 5.41). Twenty-seven males (mean age = 18, SD = 0.00) and 57 females (mean age = 24.23, SD = 5.4) took part in the experiment. All of the participants were of Italian origin. The participation was voluntary and the participants responded to invitation letters sent out by the Twins Italian Database. All participants gave informed written consent. The participants were compensated

160€ each for their participation. The inclusion criteria included no previous history of autism, uncorrectable visual impairments, neurological or psychiatric disorders and no addiction to psychoactive substances. Ethical approval was granted by the Humanities, Social and Health Sciences Research Ethics Committee at University of Bradford and SISSA Ethics Committee.

11.2.2 Design

A within-subject design was used. Participants were asked to (i) observe a presentation consisting of videos of an actor performing two different types of action (meaningless and communicative). The actor was of either in-group (Italian) or out-group (East Asian and African) membership. The participants performed specified actions (meaningless and communicative) that were different from those actions observed in (i). The dependant variable was the number of OIs formed.

11.2.3 Materials

The stimuli used in the experiment were 108 videos of simple actions being performed. Fifty-four actions were of meaningless nature and another 54 actions were communicative emblems. The videos were created using a camcorder. Each action was recorded being performed by Italian, East Asian and African actors. In total participants observed 54 actions. The actions that were to be performed by participants were written into command statements. Participants performed 54 actions in total, of which 27 actions were meaningless and 27 actions were communicative emblems. All of the action commands were translated to Italian. Part of the actions used in the experiment was adapted from Mitrenga et al. (in prep.) and Papeo and Rumiati (2012), the remainder of the actions were invented accordingly. The communicative emblems aimed to portray the typical Italian gestures. The action videos and actions statements were put into an E-prime presentation. Two preselected sets of actions were created. Depending on the set, specific preselected actions were either to be performed or observed. The observed actions were randomised for the actor type, and the order of observation and execution of actions was counterbalanced.

The actions in the videos depicted a male actor of Italian, Asian or African ethnicity. The actors were recorded in a standing up position, showing full body facing the camera. The stimuli and appearance of actors was standardised (such as white t-shirt and neutral facial expressions). All of the videos were performed by the same actor of a given ethnicity.

11.2.4 Pilot study

A pilot study was carried out on 10 people to ensure that the stimuli could be classed as communicative and meaningless. Participants saw 150 videos of actions and rated them as communicative or meaningless on a scale of 1–10 and were asked what they thought the goal of the action was. A set of stimuli were created from these results.

11.2.5 Questionnaire

In order to measure the OIs, a questionnaire was designed. The items in the questionnaire consisted of sentences written in the first person suggesting to participants that they performed the action (e.g. *I brushed my arm with a toothbrush; I waved hello*). The sentences contained 54 actions that participants performed and 54 actions that they observed. Additionally, 20 actions that were neither observed nor performed were added to the questionnaire in order to test ‘real’ false memories (see Appendix 4 for the OI questionnaire). The instructions and the action list were translated to Italian. The same as in the previous experiments, the questionnaire included the R-K-G recollection.

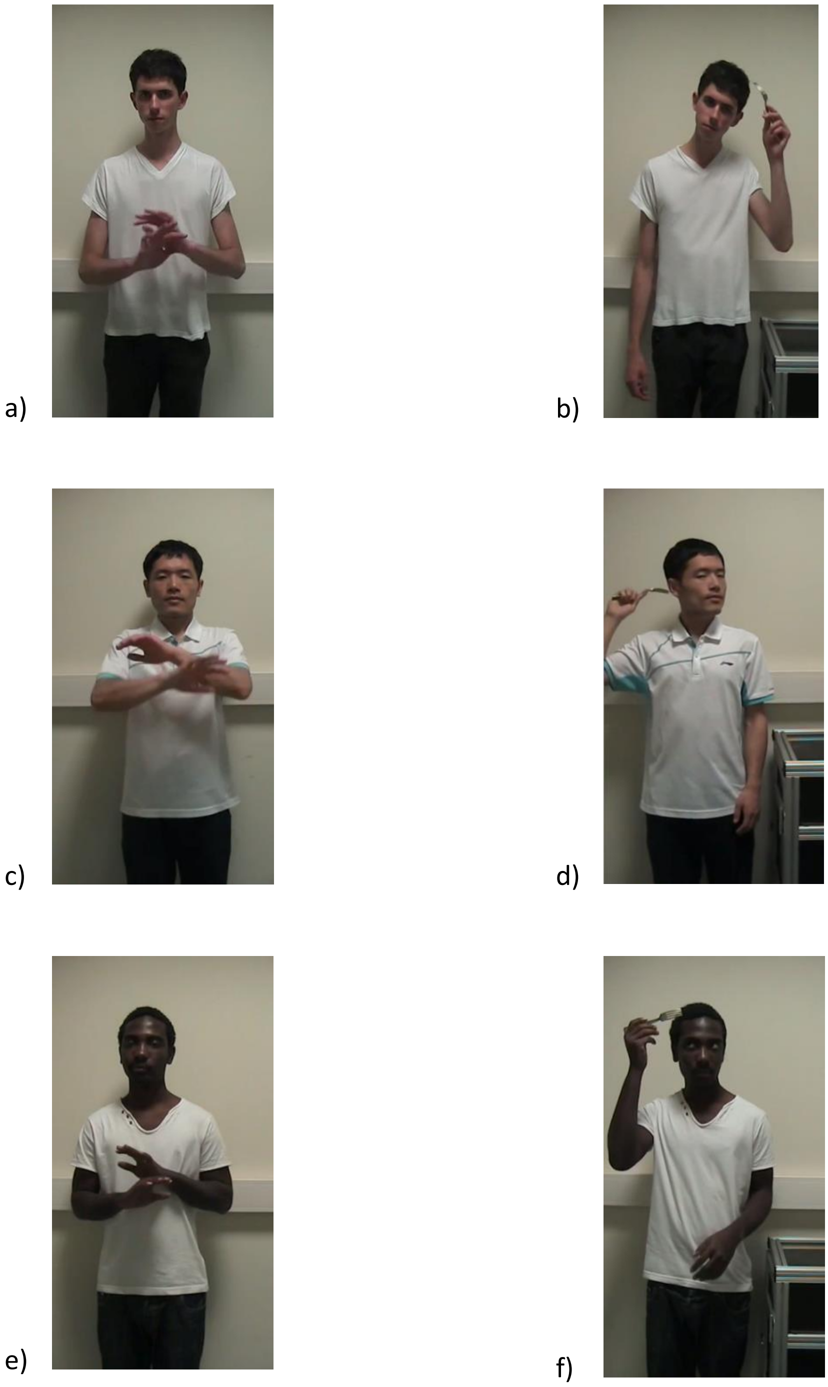


Figure 11.1 – Screenshots from the recordings of actions used in the experiment: (a) Italian actor performing a communicative action; b) Italian actor performing a meaningless action; c) East Asian actor performing a communicative action; d) East Asian actor performing meaningless action; e)

African actor performing a communicative action; f) African actor performing a meaningless action.

11.2.6 Procedure

The time of the participation was arranged with the volunteers that expressed an interest in participation after being provided with an information sheet. The experiments took place in the EEG laboratories at the International School of Advanced Studies (SISSA), Trieste. After the participants were greeted by the researcher, they were allocated to an individual room with a computer. They were seated in front of the computer and given the information sheet and consent form. After the participants had given informed written consent and familiarised themselves with the purpose and nature of the study they were instructed to watch a video presentation of 54 actions and perform 54 actions. The order in which videos of actions and action statements were presented was counterbalanced. In the performance part, the instructions explained that they will have to perform the actions described in the action statements in E-prime presentation. The participants were assured that they were not being observed nor recorded during the execution of actions. After the experiment was finished, the participants were handed a questionnaire in a pre-stamped envelope and were given a date on which they were due to fill it in (two weeks from the date on which experiment took place). A researcher phoned them one day prior to the agreed date to remind them to fill it on.

11.3 Results

The primary aim of the study was to investigate the formation of OIs as a result of observation of different types of actions (meaningless and communicative) performed by an actor of either in-group (Italian) or out-group (East Asian and African) membership.

The OIs were the actions that participant recalled with 'Remember' and 'Know' responses in the source memory questionnaire. As for the previous experiments of this thesis, the two responses were totalled to create the OI variable. The

'Guess' response was not counted as an OI error (See Chapter 5 which introduces the R-K-G procedure and Chapter 10 which is dedicated to the results of the R-K-G responses specifically). See Figure 11.2 for the number of OIs formed for different action types and according to actor's group membership.

11.3.1 OIs for different action types

Figure 11.2 shows that observation of communicative actions resulted in formation of more OIs in both group membership conditions. A similar number of actions was misattributed after observing actors of in-group (Italian) and out-group (East Asian and African) membership.

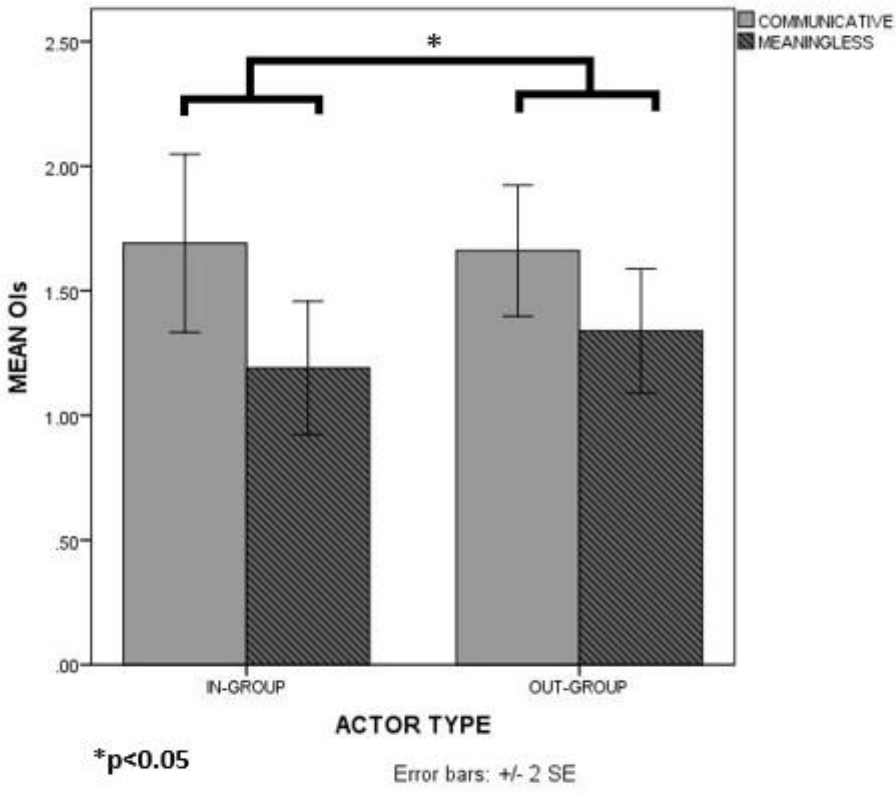


Figure 11.2 – Mean and standard errors of OIs formed after observing communicative and meaningless actions performed by in-group (Italian) and out-group (East Asian and African) actors.

The assumption of normality has not been met for the sample conditions. Non-parametric analysis is reported for this experiment.

The analysis with Wilcoxon signed ranks test showed a significant difference in the number of OIs formed for communicative and meaningless actions, $Z = -2.69$, $p<0.005$, suggesting that more OIs were formed for communicative than meaningless action overall.

11.3.2 OIs and group membership

Furthermore, the Wilcoxon signed ranks test was carried to test a difference in the number of overall OI attributions between the in-group and out-group participants. The results showed that significantly more OIs were formed after observing actors of out-group (East Asian and African) than in-group (Italian) membership. This does not support the hypothesis and is in contrast of the results of Lindner et al. (2012) who found that significantly more OIs were formed following observation of the in-group actor rather than out-group actor.

Further analysis with Friedman's test showed that there was a significant difference in the number of OIs formed following observation of the two action types performed by actors of in-group and out-group membership, $\chi^2(3) = 64.06$, $p<0.001$. Post hoc analysis with Wilcoxon signed-rank tests was conducted with Bonferroni correction applied, resulting in a significance level set at $p<0.008$. The results of Wilcoxon signed-rank tests revealed that significantly more OIs were formed following observation of (i) communicative actions than meaningless actions for the in-group actor membership ($Z = -2.66$, $p=0.008$); (ii) communicative actions for the out-group than in-group membership ($Z= -5.72$, $p<0.001$); (iii) meaningless actions for the out-group membership than communicative actions for the in-group membership ($Z = -3.4$, $p<0.001$); (iv) communicative actions for the out-group actors than meaningless actions for the in-group actor ($Z= -6.1$, $p<0.001$); and (v) meaningless actions for the out-group membership than meaningless actions for the in-group membership ($Z = -5.73$, $p<0.001$). There was no significant difference in the number of OIs formed following observation of meaningless and communicative actions for the out-group membership ($p>0.008$).

11.3.3 Memory for self-performed actions

In addition to investigating the OIs, the correct recall of self-performed actions was studied. See Figure 11.3 for the number of self-performed meaningless and communicative actions that were correctly recalled as self-performed in the source memory questionnaire.

This was analysed with a Wilcoxon signed ranks test, which did not reveal a significant difference between the recall of the two action types ($p>0.05$).

11.3.4 R-K-G analysis

To investigate the recollection judgements of the OIs, the data was analysed with Friedman's test and Wilcoxon signed ranks tests, with recollection judgment scores 'Remember' and 'Know' as dependent variables and action type (meaningless and communicative) and group (in-group vs. out-group) as independent variables. The results showed of Wilcoxon signed ranks test showed that participants of both groups more 'Remember' judgements than 'Know' judgements overall, $Z = -3.73$, $p<0.001$.

Further analysis with Freidman's test showed that there was a significant difference in the number of 'Remember' and 'Know' recollections formed for different types of actions performed by actors of in-group and out-group, $\chi^2(7) = 89.34$, $p<0.001$. Post hoc analysis with Wilcoxon signed-rank tests was conducted with Bonferroni correction applied, resulting in a significance level set at $p<0.002$. The results of Wilcoxon signed-rank tests revealed that significantly more OIs were recalled with (i) 'Remember' than 'Know' recollections for the meaningless actions in the out-group condition ($Z = -4.07$, $p<0.001$); (ii) 'Remember' recollections for the communicative actions in the out-group condition than 'Know' recollections for the communicative action in the in-group condition ($Z = -4.78$, $p<0.001$); (iii) 'Remember' recollections for the meaningless actions than 'Know recollections for the communicative actions in the in-group condition ($Z = -3.48$, $p<0.001$); (iv) 'Remember' recollections for the meaningless actions in the out-group than 'Remember' recollections for the communicative actions in the in-group ($Z = -3.85$, $p<0.001$); (v) 'Know' recollections for the communicative actions in out-group than in-group condition ($Z = -3.69$, $p<0.001$);

(vi) ‘Remember’ recollections for the meaningless actions in the out-group than ‘Know’ recollections for the communicative actions in the in-group ($Z = -4.42$, $p<0.001$); (vii) ‘Remember’ recollections for the communicative actions in out-group than ‘Remember’ recollections for communicative actions in in-group condition ($Z = -5.38$, $p<0.001$); (viii) ‘Remember recollections for the meaningless actions in the out-group than in-group condition ($Z = -5.38$, $p<0.001$); (ix) ‘Remember’ recollections for the communicative actions in the out-group than ‘know’ recollections for meaningless actions in the in-group condition ($Z = -5.23$, $p<0.001$); (x) ‘Know’ recollections for communicative actions in the out-group than ‘Know’ recollections for meaningless actions in in-group ($Z = -4.22$, $p<0.001$); (xi) ‘Remember’ recollections for meaningless actions in out-group than ‘Know’ recollection in in-group condition and (xii) ‘Remember’ recollections for communicative actions than ‘Know’ recollections for meaningless action in out-group condition. These results suggest that for all action types, participants were more likely to ‘Remember’ actions performed by the actors of out-group as having been performed by themselves.

The ‘Guess’ responses showed that participants were significantly more likely to 'Guess' actions performed by the out-group as having been performed by themselves ($Z = -6.52$, $p<0.001$). Additionally, more ‘Guess’ responses were made for communicative actions than meaningless actions, $Z = -5.97$, $p<0.001$. This is an interesting finding and similar to the findings of the previous experiments.

Further analysis showed that there was a significant difference in the number of ‘Guess’ recollections formed for the different action types and actor membership groups, $\chi^2(7) = 89.34$, $p<0.001$. Post-hoc analysis with Wilcoxon signed ranks tests showed that there were more guess responses (participants guessed that they had performed the action when they had only observed it) made for all action types for out-group stimuli than for in-group.

11.4 Discussion

11.4.1 Summary of results

The experiment aimed to investigate the OIs formed after observing meaningless and communicative actions, performed by an actor belonging to either same ethnicity (in-group) as the participants (Italian) or a different ethnicity (out-group) (East Asian and African). Based on the findings of previous studies on OIs and mirror neurones, it was hypothesised that a higher number of OIs will be formed following observation of actions performed by in-group actor (Italian) (Lindner et al., 2012). It was also hypothesised that a higher number of OIs will be formed following observation of communicative actions, as was found in the previous experiment in this thesis.

The results of the current study have found OIs to be present after observation of both types of actions, showing that it is possible to form memories of self-performance through observation of actions of others and with high confidence (as 'Remember' judgements were chosen significantly more than 'Know' judgments). The highest number of OIs formed was recorded for communicative actions, which was in line with the original hypothesis of mirror neurones and OIs and the results of previous experiments of this thesis (Experiment 1, Experiment 3 and Experiment 4). The analysis of correct source attribution revealed that execution of communicative and meaningless actions yielded a similar number of correct attributions as self-performed.

The results of in-group and out-group misattributions showed that significantly more OIs were formed following observation of actions performed by out-group actors (East Asian and African) than the in-group actor (Italian). This does not support the initial hypothesis, and is also not in line with the findings of a similar study on this subject (Lindner et al., 2012). Lindner et al. (2012) found the opposite effect (more OIs made for the in-group condition) in a similar paradigm and attributed this effect to the mirror neurone activation not being as strong for out-group actors as in-group actors during the action observation, which consequently did not yield as high a number of misattributions as for the in-group condition.

However, a difference in the stimuli used in the current study and Lindner et al. (2012), makes it challenging to compare the two results. In the current study, the actions were both communicative and meaningless actions, whereas Lindner et al. (2012) used only meaningful actions (as it is assumed based on the examples given). More importantly, Lindner et al. (2012) did not include other characteristics apart from the skin colour in the stimuli, where in the current study actors' faces were included in the videos. According to Desy and Lepage (2012), physical characteristics such as skin colour are not as strong a factor in prejudice towards a race, which is more likely to be present where other features are present, e.g. a face. Seeing a face could hint at more cultural biases than only a skin tone.

However, the question remains as to why the number of misattributions was higher for the out-group condition in the current study.

Some imitation research also shows different neural activation during imitation of actions of individuals of different races, with the activation being higher for the members of out-group (Losin et al., 2012). This is thought to be linked with possible compensation mechanisms required to imitate actions of unfamiliar groups (Losin et al., 2012). Additionally, Earls et al. (2013) found that imitating actions of own-race actors rather than other race, resulted in higher activation in brain areas associated with action imitation, such as inferior parietal lobule and superior parietal lobule.

In light of the different findings between this and Lindner (2012), future studies should look at the OIs in the context of race further. It would be interesting to investigate the effect of the magnitude of cultural features present in the observation (e.g. absence of face).

Examining the underlying neural activity during observation of actions performed by actors of different races and comparing it to the source attribution of these actions could shed light on whether or not any mirroring mechanisms could stand behind the OI effect. This study provided little support for this but more research is needed as, as far as I am aware, this is only the second study looking at in-group and out-group stimuli to study OIs.

11.4.1 Conclusion

The current study showed that action observation can result in false memories of self-performance. This was found after observation of both communicative and meaningless actions. However, the OI formation was significantly higher for communicative actions. This finding is in line with the results of previous experiments of this thesis, and could possibly suggest involvement of mirror neurones. It is unclear why the highest number of misattributions was formed following the observation of out-group individuals. If mirror neurones were involved in the formation of OIs it was predicted the highest number of OIs should be made for in-group communicative actions, which was not seen here. Future research should address this by investigating underlying neural activity in OI formation and group membership.

11.5 Highlights

- Previous studies have shown that humans demonstrate different neural activation during observation of different races.
- Observation of in-group individuals resulted in higher activation of areas associated with mirror neurone activity than observation of out-group individuals (Gutsell and Inzlicht, 2010).
- Lindner et al. (2012) found significantly reduced numbers of OIs following observation of out-group individual compared to in-group individuals.
- It was hypothesised that the highest number of OIs would be formed following observation of communicative actions performed by the in-group actor.
- The results showed that observation of communicative actions resulted in significantly more OIs than meaningless actions.
- All OIs were made with significantly more high confidence judgements ('Remember') than lower confidence judgements ('Know').

- Significantly more ‘Remember’ recollections were made for the actions performed by out-group actors than ‘Remember’ and ‘Know’ recollections for in-group actors.
- Guess responses however show that participants are more likely to ‘Guess’ that they had performed an action for all action types in the out-group condition than in the in-group condition.
- Significantly more OIs were formed following observation of out-group individuals, regardless of the action type that was observed.
- The finding is not in line with the previous literature.
- More research on OI and in-group/out-group action observation is needed as this is only the second study investigating this.
- Future studies should investigate the neural activity underlying observation of action execution by actors of different race membership.

Some of this material can be found in Mitrenga et al. (in prep.) – ‘The social aspect of observation inflations. Misattributing the actions of in-group and out-group actors’.

Chapter 12

General discussion and summary

12.1 Introduction

The aim of this thesis was to investigate the newly researched type of source monitoring error, namely the observation inflation (OI) effect. In this effect, the observation of actions being performed results in formation of memories of one actually performing those actions themselves. This thesis comprises of a series of experiments that investigated this effect under different conditions. Under investigation was whether (i) observation of different types of actions (meaningful, meaningless and communicative) can influence the memories of self-performance, (ii) older age makes one more susceptible to OIs; (iii) instruction at the recall stage can influence the formation of OIs; (iv) whether OIs can be influenced by actor's race and (v) the OI effect can occur in reverse i.e. can performed actions be remembered as observed? I have termed this effect as self-action inflations (SAIs). All the experiments implemented the R-K-G questionnaire to investigate the recollective experience of the OIs and SAIs formed. This chapter will summarise the main objectives and results of each experiment. Following that, limitations, implications and ideas for future will be presented.

12.2 Summary of all the Experiments

Limited literature on the subject of OIs suggests that the effect is caused by errors in source monitoring (Lindner et al., 2010; Lindner and Davidson, 2014). Lindner et al. (2010) proposed that the source confusion errors could be formed due to mirror neurone activity and that when one observes the action, similar or the same brain activity is present as to when the action was actually performed. Hence, the observed actions could be misremembered as actually having been performed by the participants as a result of this mirror neurone activity causing source confusion.

Experiment 1 (Chapter 6) focused on creating an experimental design that would allow studying OIs and the possible involvement of mirror neurones in this effect. To test this behaviourally an experimental design involving observation and execution of different action types was created. The types of actions used in Experiment 1 were meaningful, meaningless and communicative actions. These types of actions were chosen as the mirror neurone and imitation research suggest that they are all processed differently (Ferrari et al., 2005; Rumiati and Tessari, 2002). Mirror neurone research has shown that the observation of communicative and meaningful actions results in higher brain activation in the motor areas in the brain than when meaningless actions are being observed (Andric et al., 2013; Husain et al., 2012). Additionally, research on imitation shows an imitation advantage of meaningful and communicative actions over meaningless actions (Rumiati and Tessari, 2002; Carmo and Rumiati, 2009).

The experimental stimuli were then created to fit within the three action type categories. The videos depicting a female actor performing the actions were recorded by the researcher. A pilot study was run to ensure the actions were portraying clear and unambiguous meaningful, meaningless and communicative actions. The participants taking part in the pilot study were asked to rate the videos of actions on a 1–10 scale of how meaningful they considered the actions to be. Additionally and importantly, the participants stated what they considered the goal/outcome of the action to be. The 30 communicative and 30 meaningful actions that scored the highest on the meaningfulness scale were chosen as stimuli. Also, 30 meaningless actions that scored the lowest were chosen as meaningless stimuli.

If meaningful and communicative actions activate mirror neurones as shown in the literature (e.g. Montgomery et al., 2007; Ferrari et al., 2005) to a higher extent than meaningless actions (which may present with little or no mirror neurone activity), the matching activation could then result in confusion of the sources of the memory and consequently misattribution of observed actions as self-performed (the OI effect). Therefore, it was hypothesised that communicative and meaningful actions would result in higher levels of OIs than meaningless actions.

In the first phase of Experiment 1, the actions were randomly assigned between the two conditions – 'observe' and 'perform' in which participants performed a set of actions and observed a set of actions. In the ‘perform’ condition, participants were instructed to perform the actions described in statements presented on the computer screen, for example ’Highlight a sentence in the document’. The objects needed for execution of meaningful and meaningless actions were provided to participants. In total, participants performed 30 actions. In the ‘observe’ condition, participants were instructed to watch the videos of actions being displayed on the computer screen. In total, participants observed 30 videos of actions. The second phase of the experiment, which took place either one day, one week or two weeks after the test phase, consisted of a source memory test, where participants were asked which actions they remembered performing themselves. The source memory questionnaire included (i) statements that described actions which participants had ***performed*** in the experiments; (ii) statements that described actions participants had ***observed*** in the experiments and (iii) actions that were neither performed nor observed by participants. All action statements were written in the first person, suggesting to participants that they performed the actions, for example ‘I stapled a document’. Following the initial Yes/No recognition of each action statement, participants had to then decide whether they ‘Remembered’, ‘Knew’ or ‘Guessed’ that they performed the actions.

The results of Experiment 1 revealed that participants formed memories of self-performance as a result of observation of all three types of actions (OIs). However, participants were more likely to form OIs for actions that were communicative and meaningful rather than meaningless. This result partially supported the initial hypothesis, that more communicative actions will be remembered as self-performed than meaningless actions. Experiment 1 also found that overall source memory accuracy declines as the time delay of testing increases, showing that more OIs were formed after two weeks’ time delay rather than one week and one day. This is similar to the results of Lindner et al. (2010) who found that more OIs were made after a two week than one week testing delay. This is also in line with result of other studies that show that memory accuracy deteriorates with time (Porter et al., 2010).

The results of Experiment 1 support the speculative hypothesis that mirror neurones could potentially be involved in the OI effect, since higher numbers of OIs were formed after observation of communicative than meaningful and meaningless actions. Seemingly, the source monitoring errors are causing the OIs and the source attribution becomes more challenging possibly, if the mirror neurone hypothesis holds, due to the shared sensorimotor experience during observation and execution of actions.

Regarding the correct source attributions of actions that were actually performed in Experiment 1, the highest number of correctly recalled actions was found after performing communicative actions followed by meaningful actions. Fewest correct source attributions were made after executing meaningless actions. This is an interesting finding, as the communicative actions resulted in both the highest number of correct source attributions but also the highest number of OIs. This suggests that memory for communicative actions has a strong aspect of self-reference attached to it. Manzi and Nigro (2008) showed that performed actions are recalled at a higher accuracy than observed actions, and the recall rates for performed actions are higher than for misattributions to the incorrect source. This effect could be due to a self-performance advantage, which shows that the actions that are performed by the individual are generally remembered better than observed actions (Manzi and Nigro, 2008). This was demonstrated by the results of Experiment 1, where actions that were actually performed by participants were recalled at higher rates than OIs. Importantly, this effect was only present for the communicative and meaningful actions, which again suggests that the three types of actions are processed differently. The lower rate of correct source attribution of meaningless actions could be a result of the unfamiliarity.

Furthermore, Experiment 1 showed than in addition to making misattributions of self-performance, participants formed false memories for actions that were neither observed nor performed by them.

The general conclusions from Experiment 1 were that observation of actions can results in memories of self-performance (OIs). The OIs were significantly higher after observing communicative and meaningful rather than meaningless actions. The pattern of OI formation for different action types might suggest involvement of mirror neurones. If mirror neurone activity was making the source monitoring more challenging, the same effect should be visible in reverse. This means that the misattribution of performed actions as observed being performed by somebody else would be possible. This then formed the main objective of Experiment 2 (Chapter 7), where misattributions of performed actions as performed by somebody else were studied.

In Experiment 2, the same set of experimental stimuli and procedure was used, with the exception of source memory questionnaire. The questionnaire this time, asked participants if they recalled observing a person performing a given action, instead of asking them if they remember performing the actions themselves (for example, the participant had to answer whether they remember observing ‘sticking a note to a wall’). The R-K-G recollection/confidence judgements were also investigated as in Experiment 1.

The results showed that participants misattributed actions that they performed themselves in the experiment as performed by others. This phenomenon was termed self-action inflation (SAI). The results revealed that participants formed more SAIs for meaningless actions and communicative actions rather than meaningful actions. This result is only partially in line with results of Experiment 1, where the meaningless actions were the least misattributed actions as self-performed. This was a surprising finding and problematic for the mirror neurones hypothesis.

The possible cause for the high SAIs after performing meaningless actions could be the ‘it-had-to-be’ you effect (Manzi and Nigro, 2008). In this effect, actions of unique nature are unfamiliar to the individual and are consequently attributed to other persons. Due to the characteristics being so unfamiliar, they tend to be judged as unlikely to have been performed (Manzi and Nigro, 2008). Because meaningless actions are unfamiliar and unique to participants, it is more difficult to attribute the actions to oneself. Even though the actions are actually performed by participants (which would suggest a stronger and more accurate memory for them), the brief execution of those actions in the experimental procedure did not seem to result in accurate memory of them.

Communicative actions on the other hand, are familiar actions that are observed or performed in everyday life. Contrary to meaningful actions, they only consist of hand manipulation and do not involve objects. Object presence could make the actions more distinguishable and make them easier to be attributed to the correct source. While the meaningful actions involved object manipulation, the memory trace for those actions might have been stronger and participants remembered them better as self-performed. This is reflected in the correct recall of observed actions, where the meaningful actions were recalled correctly as observed at the highest rate in Experiment 2.

Similarly as with the OIs, SAIs increased over time, showing the highest level of misattributions after two weeks than one day and one week.

Interestingly, the mean number of errors formed between Experiment 1 and 2 significantly differed, showing that significantly more SAIs were formed in Experiment 2 than OIs in Experiment 1. This is interesting since the two experiments were identical in the procedure, varying only in wording of the questionnaire.

The results suggest that it is easier to attribute actions to other people than to oneself. Similar result was found by Manzi and Nigro (2008) who found that misattribution of self-performed actions as observed (SAI) was significantly higher than misattribution of observed actions to oneself (OI).

If the original mirror neurone hypothesis held, then the same pattern of misattribution as observed in Experiment 1 should have been observed for the

SAIs in Experiment 2. This hypothesis however was not supported, as it was found that significantly more communicative as well as meaningless actions resulted in SAIs than meaningful actions. This could be potentially a result of a biased questionnaire suggesting a source of memory to participants.

One of the aims of this thesis was to create a paradigm that would allow testing the OI effect as accurately and efficiently as possible. Since the mean OIs in Experiment 1 were relatively low a better paradigm was needed to induce higher numbers of inflations. Therefore the effect was further tested in a cohort of elderly participants (mean age = 72.87) in Experiment 3, as it was expected that the elderly will make more OIs than young participants. Hence, this would allow investigating the OIs for different types of actions better. According to source memory literature, the source monitoring accuracy declines with age (Haj et al., 2012; Nedelko et al., 2013).

The same experimental procedure was used as in Experiments 1 and 2, with the exception of the source memory test which participants took only after a two week time delay. This was done because both in Experiment 1 and 2, the two week time delay resulted in the highest number of misattributions when compared to one day and one week testing delays.

The results of Experiment 3 revealed that the elderly participants formed significantly more OIs after observing communicative than meaningful and meaningless actions. This finding is in line with the results of Experiment 1, however, in Experiment 3 the difference in the OIs formed for communicative and meaningful actions reached statistical significance. This further supports the hypothesis that mirror neurone activity could make the source monitoring more challenging. Furthermore, compared to young participants in Experiment 1, elderly participants made significantly more OIs in Experiment 3 overall. This is supported by previous research on memory distortions in the elderly, showing that source monitoring accuracy decreases with age (Haj et al., 2012; Hashtroudi et al., 1989).

Additionally, Experiment 3 found that elderly participants formed significantly more false memories than younger adults. This shows that elderly are more likely to recall performing an action when in fact they neither observed nor performed it.

Given that there was a seemingly strong bias from the wording of the questionnaire as seen by the results of Experiment 2, which showed that significantly more SAIs were formed than OIs in Experiment 1, it was assumed that the wording of the questionnaire could be potentially biasing the recall of actions since the stimuli and procedure in both experiments were the same. Eliminating the suggestibility from the questionnaire was the objective of the next experiment where participants had to make the decision about the source of their memory themselves. This allows for a controlled investigation of OIs and SAIs. Experiment 4 therefore investigated the possible bias of the source memory questionnaire on the OIs and SAIs. The experiment followed the same procedure as Experiments 1, 2 and 3; however, the instructions on the source memory questionnaire were modified. Instead of source recognition of either self-performed or observed actions, participants had to recall the source of the action. For each action participants had to answer whether they recall 'observing' or 'performing' it. An example of wording of the action statement would be 'Flashing a torch' and the participants had to tick either 'I recall performing this action' or 'I recall observing this action'. This was done to eliminate possible biased results due to wording of the questionnaire, resulting in strong suggestibility effects potentially hiding any real effects (as in Experiments 1, 2 and 3).

The results of Experiment 4 revealed that the highest number of source memory errors overall was formed for communicative actions. Additionally, in Experiment 4, OIs and SAIs were found to be as equally likely to be formed. Although there were more OIs formed compared to SAIs, the difference was not found to be statistically significant. This is a different result from that of Experiment 1 and Experiment 2, where more SAIs were formed in Experiment 2 than OIs in Experiment 1. This result shows that the mean SAIs decreased in Experiment 4 (as compared to Experiment 2) and increased for OI in Experiment 4 (as compared to Experiment 1) making this a better and more controlled paradigm to investigate OIs and SAIs.

As for the correct source attribution, participants demonstrated higher memory accuracy for the actions that they performed themselves than the action they observed. This means that participants were more accurate when remembering actions they performed themselves, which is in line with the self-performance advantage theory (Manzi and Nigro, 2008). Manzi and Nigro (2008) found a higher recognition rate for actions that were self-performed than observed; and also Senkfor et al. (2002) who found participants had the highest recall accuracy for performed rather than observed actions.

Experiment 4 controlled for any methodological issues hiding potential effects. The results have also supported the speculative hypothesis that mirror neurones may stand behind OI and SAI formation, as the results show that both action observation and action execution result in source misattributions. In particular, the high level of misattributions formed for communicative actions may suggest mirror neurone involvement in the OI and SAI effects. The results of Experiment 4 also highlighted the importance to control for suggestibility in questionnaires in source memory error research.

It was of interest in Chapter 10 to investigate the recollective experience of OIs, SAIs and correct source attribution for performed and observed actions formed in Experiment 1 (Chapter 6), 2 (Chapter 7), 3 (Chapter 8) and 4 (Chapter 9). The R-K-G recollection procedure was included in each source memory questionnaire for each experiment, where participants were required to specify whether they 'Remembered', 'Knew' or 'Guessed' that they performed or observed the actions. This is a common procedure used in false memory research and as far as I am aware has not been used in any research investigating inflations (apart from Manzi and Nigro, 2008) nor in any mirror neurone research (as mirror neurones research in relation to memory tends to study implicit memory e.g. priming, rather than episodic recollection).

The most important findings from this analysis was that in the control Experiment 4 (Chapter 9) it was found that significantly more OIs were recalled with ‘Remember’ than ‘Know’ recollection and this difference was the strongest for communicative actions i.e. communicative OIs were remembered (incorrectly) with strong qualitative details with a strong feeling of knowing and high confidence that the 'errors'/inflations were indeed correct. Although speculative, this potentially provides support for the mirror neurone hypothesis because if observation of communicative actions results in higher mirror neurone activity than meaningless and meaningful actions, this could lead to experience similar to actually performing those actions. This shared sensorimotor activation could then manifest itself with highly detailed memories of performance, even though the actions were only observed. Thus, the high rate of ‘Remember’ recollections could suggest highly detailed false memories, possibly a result of higher mirror neurone activation than meaningful and meaningless actions.

Interestingly and surprisingly, a different pattern of recollections was found for SAIs in the same experiment. The results revealed that SAIs were recalled with a similar number of ‘Remember’ and ‘Know’ responses. This is a different result from that of OIs recollection in the same experiment, which showed significantly more OIs were recalled with ‘Remember’.   It is clear that the results of the OI experiment here can potentially support the involvement of mirror neurones in the formation of inflations as the OIs for communicative actions not only resulted in significantly more ‘Remember’ than ‘Know’ recollections, but the ‘Remember’ recollection rate was significantly higher than that for meaningful and meaningless actions. However, again it would be expected that if mirror neurones were involved, the result would also be seen in reverse and in the controlled paradigm of Experiment 4, there was no suggestion that this was the case. More research on SAIs is now needed to investigate again whether there are biases of some kind from the experimental design or these are true effects of action inflation and recollection judgments are genuinely different between the SAIs and OIs.

The results of Experiment 1 and 3 are in line with those of Manzi and Nigro (2008), whose study focused on the recollective experience of correct recall of performed and observed actions. Manzi and Nigro (2008) did not find any significant difference in the number of 'Remember' and 'Know' recognitions of misattributions, which means participants were equally likely to recall the actions with either of recollections. Also, it was found that misattributions of observed actions as performed (termed OIs in this thesis) were more likely to be recalled as 'Remembered' than actions that were performed as observed (termed as SAIs in this thesis). Regarding the correct source attribution, the results reported in this thesis are also in line with Manzi and Nigro's (2008) results, showing that the correct recognition of both performed and observed actions is most likely to be recalled as 'Remembered'.

However, the results of Experiment 1 and 2 were possibly biased by the wording of source memory questionnaire which suggested the source of memory to participants. In Experiment 4, where this was controlled for by giving the participants the option to differentiate between the sources of their memory (observed vs. performed), the results have shown that significantly more OIs were recalled with 'Remember' than 'Know' recollection. The retrieval procedure implemented in Experiment 4 is methodologically similar to the one used in Manzi and Nigro's (2008) study, however, based on the examples given, the actions used in Manzi and Nigro's (2008) study were only of meaningful nature. The type of action used in their experiment and experiment of this thesis could affect the pattern of recollection reported.

Additionally, in Experiment 5 the social context of OIs was investigated, where the misattributions were studied following observation of actors of different races. In the experiment, participants observed 54 videos of actions performed by Italian, East Asian or African actors. Participants were also required to perform 54 actions. Both observed and performed actions were either of meaningless nature or communicative emblems. The results of a source memory test revealed that overall (i) participants formed significantly more OIs after they observed communicative rather than meaningless actions and (ii) significantly more OIs were formed following of out-group actor (African and East Asian) than in-group actor (Italian). The results were only partially in line with the initial hypothesis, in that significantly more OIs were formed for communicative than meaningless actions. However, the higher level of inflations for the out-group actors was surprising and against initial hypothesis and previous research in this subject area. This is not clear why such pattern of inflations was found and it is necessary to extend the research on OIs and race more since, as far I am aware, this is only a second experimental study that has researched OIs in the context of race. The experiment of Lindner et al. (2012) on this subject has found an opposite result, where more OIs were made after observing in-group actor. This is proposed to be a consequence of overlapping brain activity between performance and observation of actions of members of own race, in contrast with other races (Lindner et al., 2012).

To summarise, Experiment 1 studied the hypothesis that mirror neurones could potentially be involved in the OI effect (Lindner et al., 2010). To investigate this, the pattern of misattributions of observed actions as self-performed was investigated for different types of actions (meaningful, meaningless and communicative) that were observed. Experiment 1 revealed that observation of actions can result in memories of performing those actions. Additionally, participants formed significantly more OIs after observation of meaningful and communicative actions than meaningless actions. To test the mirror neurone hypothesis further, the effect was looked at in reverse, i.e. if self-performed actions can be misattributed as actions performed by others (SAIs) in Experiment 2. The results revealed that performance of meaningless and communicative actions were the most likely to result in SAIs. Because the numbers of OIs formed in Experiment 1 were very low with many participants scoring at the floor level, the effect was investigated in the group of elderly who could potentially form more OIs. Similarly, as for Experiment 1, Experiment 3 showed that significantly more OIs were formed following observation of communicative actions than meaningful and meaningless actions. Additionally, elderly participants in Experiment 3 formed significantly more OIs overall than young participants in Experiment 1 showing that this is a good cohort in which to study inflations. In Experiment 4, different source retrieval instructions were tested in a modified questionnaire. This was important as results from Experiments 1 and 2 suggested there was a strong bias from the wording of the questionnaire in the test phase of the experiment. The results of Experiment 4 showed the highest number of misattributions, regardless of the error type, was made for communicative actions. This further supports the possible role of mirror neurones in source memory error formation. Additionally, in Experiment 1, 2, 3 and 4, the memory for self-performed actions was characterised with higher source recall accuracy, suggesting better memory for actions that were self-performed. The results of Experiment 5 further supported the notion that action observation can result in memories of self-performance. It further supported the speculative hypothesis of mirror neurones, since significantly more OIs were formed for communicative actions than meaningless actions.

In Chapter 10, the recollective pattern of OIs and SAIs was analysed. In Experiment 4, the control experiment, significantly more OIs were recalled as 'Remembered' than 'Known' and significantly more communicative actions were recalled as 'Remembered' than meaningful and meaningless actions, which supports the initial mirror neurone hypothesis. If observation of communicative actions triggered strong mirror neurone response, this could potentially result in stronger memories of self-performance than in case of meaningless or meaningful actions. The 'Remember' response indicates strong recollective detail of memory. However regarding the findings in Experiment 4 for SAIs, which showed no significant difference in the number of recollection judgements made overall, is problematic for the mirror neurone hypothesis, since it was expected that the same pattern of recollection would be present for OIs and SAIs in the Experiment 4. This warrants further investigation.

12.3 Limitations, implications and future directions

The general assumption that different types of actions will result in different patterns of OIs and SAIs was based on the hypothesis proposed by Lindner et al. (2010) that mirror neurones may stand behind OIs. This is a novel concept proposed as an explanation for source memory error formation, researched in, as far as I am aware, only a small number of studies (Lindner et al., 2010; Schain et al., 2012; Lindner and Davison, 2014). Mirror neurones are active when one is performing an action and observes the same action being performed by somebody else (Ferrari et al., 2005; Gallese et al., 1996). The perceived action is then 'experienced' by an observer, at least at the neural level. Since the discovery of mirror neurones in the 1990s (Gallese et al., 1996; Rizzolatti et al., 1996), mirror neurones have been extensively researched in behavioural studies, (Brass et al., 2001), brain imaging studies (Ferrari et al., 2003) and also in single cell recordings (Mukamel et al., 2010). Studies on mirror neurone activity and action type have found a higher level of mirroring activity when individuals observe actions that are meaningful and communicative (Montgomery et al., 2007; Husain et al., 2012) and that observation of communicative actions can elicit the strongest mirror neurone activity (Ferrari et al., 2005).

Communicative actions used in the experiments discussed in this thesis, can be considered communicative emblems (Andric et al., 2013). The communicative emblems convey the meaning of the actions through gestural symbol. Previous studies have found that communicative emblems are likely to be processed in the same way at the neural level as speech and gestures accompanying speech (Andric et al., 2013). This can give the communicative emblems the advantage of triggering the neural brain activity to a higher extent than meaningful actions. Thus the initial general hypothesis was that meaningful and communicative actions would result in more OIs than meaningless actions, because of possible brain activity being mirrored during observation of those actions. This hypothesis is speculative at this stage but was supported by the results of experiments in this thesis, showing that (i) observation of communicative actions resulted in significantly more OIs than observation of meaningful and meaningless actions (Experiment 1, Experiment 3 and the OIs in the controlled Experiment 4). Additionally, when the effect was tested in reverse, it was observed that significantly more SAIs were formed for communicative actions in the controlled Experiment 4. These results support the hypothesis of the possible involvement of mirror neurons in formation of source memory errors. The increased familiarity of actions and experience of performing them could result in the source of the action being more difficult to monitor or cause participants to mistake the actions as actually self-performed.

Although the highest number of SAIs was for the communicative and meaningless actions in Experiment 2, which is potentially problematic for the mirror neurone hypothesis, this could be explained by a bias effect from the wording of the questionnaire, hence why Experiment 4 was carried out which controlled for this. The results of Experiment 5 are also problematic for the mirror neurone hypothesis, since it was initially hypothesised that more OIs will be formed for the actions performed by an in-group actor. The results revealed the opposite, where significantly more OIs were formed for the actors of out-group membership. If the mirror neurone activity is stronger during observation of actions of same race actors than other race actors, it would be logically plausible to expect same race actor's actions would be more likely to be misremembered as self-performed. However, this is only a speculative hypothesis of the mirror neurone involvement that is why more research involving brain imaging is necessary.

Even though most of the results of the experiments of this thesis support the hypothesis and suggest mirror neurones could be involved in the formation of OIs and SAIs, the data obtained is only behavioural and as for all behavioural studies investigating mirror neurone activity, neuronal activity was not directly measured. It has been reported that there is very little or no activity during observation of meaningless actions (Rizzolatti, 1999), but this has never been tested in the context of OIs or even source monitoring. Although, some of the behavioural results of experiments in this thesis support the possible involvement of mirror neurones, it should be tested further using brain imaging. As far as I am aware, OIs have not yet been formally tested using imaging techniques. Furthermore in this thesis the R-K-G recollection was investigated behaviourally. Future research should also look at neural activity underlying the R-K-G retrieval of different types of actions. Because mirror neurones are usually associated with forms of implicit memory (e.g. priming) and the R-K-G measures episodic recollection, this issue should be investigated using imaging, a common technique employed in the R-K-G procedure (e.g. Gimbel and Brewer, 2011; Rugg, 2012). Imaging is used to investigate this procedure in part because of the very subjective nature of the R-K-G judgements. However, the results of the R-K-G recollection judgements in this thesis do support mirror neurone involvement, at least in part, in that significantly more communicative actions were recalled as 'Remembered' than 'Known'; and significantly more 'Remember' recollections were made for communicative than meaningful and meaningless actions.

Another issue to consider is whether the level of misattributions could have been biased by the real-life enactment and observation of those actions in everyday life. As discussed in Chapter 4, communicative and meaningful actions are highly familiar actions that are performed and observed regularly. Thus, it is likely that participants could have performed and observed those actions in the time period between the experiment and source memory questionnaire. Because the communicative emblems and meaningful actions are strongly associated with everyday interactions, it could make them more susceptible to interference from enactment and observation than meaningless actions. It has been previously demonstrated that performing both communicative and meaningful actions leads to a better recall of these actions, a so called 'enactment effect' (Senkfor et al., 2008). It has been suggested that enactment of action and motoric information associated with it are stored in the long–term memory at the encoding, which then leads to a more efficient retrieval (Senkfor et al., 2008; Allen et al., 2007; Hornstein and Mulligan, 2004). For example, Senkfor (2008) showed that retrieval of actions that involved object manipulation but not pantomimes engaged the motor cortex to a much greater extent. Additionally, the research has shown that memory for goal-directed actions encoded through observation is equally detailed as memory encoded through enactment (Schult et al., 2014; Steffens, 2007). This shows that participants' memory for actions that were observed/executed in the experiments, could have been affected by latter encounters of the same or similar actions during the period of testing time delay.

Especially since the highest number of misattributions was formed for communicative and meaningful actions that are likely to be encountered in everyday life. The meaningless actions on the other hand, are unfamiliar and are not likely to be observed or performed outside the experiments, thus the likelihood of them interfering with participant's source memory is much lower. Although enactment and observation improve the memory for actions, in that participants are more likely to recall occurrence and details associated with them, it seems to have a negative effect on source memory. For example, Hornstein and Mulligan (2004) showed that enactment and observation of actions improves item memory for objects associated with the action when participants classified a list of objects as 'new' or 'old'. However, significant number of the actions presented in the list was wrongly attributed between the performed and observed conditions. Hornstein and Mulligan (2004) found that observed actions were wrongly attributed as self-performed and also self-performed actions were misattributed as observed. Interestingly, it was found that significantly more misattributions of self-performed actions to other person were made, which is the same result as in Experiment 4 (Chapter 9), where significantly more SAIs were formed than OIs.

This evidence fits in with the reconstructive theory of remembering and retroactive interference effect (Dewar et al., 2007; Bartlett, 1932; Loftus, 1975). The acquisition of new memories of actions following the experiment could have affected the already stored information in the long-term memory. In the experiments, the time between encoding of actions and subsequent recall in the source memory questionnaire was potentially filled with acquisition of new memories of the same actions that were presented in the experiment. This could interfere with memory source attribution and lead to formation of misattribution in the time period between the encoding of actions and recall. Hence, the higher level of misattributions was observed for meaningful and communicative actions.

12.3.1 Experimental design

Certainly, as discussed above, OI and now SAI research would benefit from using brain imaging techniques to observe the brain activity during the encoding of different types of actions and retrieval during the source memory tests. The experiments of this thesis provide a good grounding in which to take this further and implement using brain imaging. Part of the aims of this thesis was to create an effective paradigm to test OIs made for different types of actions as this has never been done before (as far as I am aware). Overall, the experimental design turned out to be a successful tool for studying OIs for different types of actions. The experiments revealed that patterns of OIs and SAIs varied after either observation or execution of different types of actions (meaningful, meaningless and communicative). Furthermore, the results strongly show that to get the most significantly meaningful data from OI and SAI research (in particular to avoid floor effects) that the time delay between the study phase and the questionnaire should be two weeks, or should be tested in elderly participants (SAIs not tested in this cohort here but is an important area for future research). Similarly low numbers of OIs were found in Lindner et al. (2010) and Manzi and Nigro (2008) who found misattributions of observed actions as self-performed with a mean of 0.04 and self-performed actions as observed as being performed by somebody else – SAI - with a mean of 0.18 (Manzi and Nigro, 2008). From my own experience and because most of this type of research tends to be carried out at university institutions, it is usually easier to recruit young participants than elderly, so to take this research forward, whether it be more behavioural studies or using the aforementioned imaging techniques, a two week time delay between study phase and test phase should be implemented. Further testing should also look at longer time delays to see if even more OIs and SAIs are made. However this potentially comes with other challenges such as participant drop-out which was found in this study more at two weeks than at the shorter time delays. This would be lessened with a stronger incentive for participants to return.

12.3.2 Stimuli

Another area for future study is manipulations to the video stimuli. In all experiments, participants were shown videos depicting a female actor performing different actions. Future experiments should control for the gender of the actor to eliminate any possible gender bias. Although there is a great amount of literature looking at the differences in gender and mirror neurone activity, the objective of these studies is not the gender bias based on the sex membership of the actor performing the action. The past research shows some sex differences in mirror neurone activity, particularly that female brains exhibit larger gray matter volume in the areas of mirror neurone activity – pars opercularis and inferior parietal lobule (Cheng et al., 2009; Cheng et al., 2008; Hadjikhani et al., 2006; Yamasue et al., 2009). However, Cheng et al. (2009) found that although females suppressed the mu rhythm during observation of hand movements to a higher degree than males, the perceived sex differences of the presented hand (either female, male or androgynous) did not elicit a significantly different response between the sexes (Cheng et al., 2009). Additionally, Lindner et al. (2010) in their OI study initially tested if sex of the actor executing the action has any influence on the pattern of OIs formed and found no gender effect in their results (Lindner et al., 2010). Therefore it seems unlikely that there will be any effect of gender of the actor, but this is yet to be investigated regarding different types of actions and OIs and has never been investigated at all with SAIs. Given the large number of SAIs made for meaningless actions as compared to OIs in the initial experiment investigating SAIs, Experiment 2, an effect that goes away when the bias from the questionnaire is controlled for in Experiment 4, it seems that SAIs may be more susceptible to biases than OIs. This makes sense in the context of the 'it had to be you' effect (Manzi and Nigro, 2008). Therefore a gender bias should be investigated in this type of inflation.

Another methodological aspect that could be investigated in the future is the perspective from which the action execution videos were recorded. In the experiments discussed in this thesis, all of the communicative actions were depicted from the third person perspective (camera facing the actor), with the actor's face visible in all the video recordings. This was not the case with the meaningful and meaningless actions, where not all the videos included the actor's face, as the nature of the action did not require the face to be visible to execute the action. For example in some of the actions only hands manipulating the objects were visible (e.g. hands moving a stapler and stapling a document). Interestingly, Schain et al. (2012) found that OI effect was reduced where more discriminatory features were available during the observation, i.e. facial features available instead of only hands. Additionally, when given extra instructions to focus on the face during action observation, the OI was eliminated (Schain et al., 2012). This is interesting as in the experiments of this thesis, the communicative actions which all include a visible face, resulted in the highest formation of OIs.

Since the results of Experiment 5 were different to those of Lindner et al. (2012), future work should study the OIs in the context of race more. In order to find out whether mirror neurones play a role in the OIs effect, the underlying neural activity should be investigated during observation of actors of different races performing the actions.

12.3.3 Neuropsychological patients

Importantly, these results demonstrate the malleability of memory and that it is possible to confuse the source of performed and observed actions.

Future research on SAIs could look at this effect in the context of schizophrenia. Similar effects of ‘underattribution’ is common in schizophrenia patients, where self-performed actions are misattributed to other entities (Jeannerod and Pacherie, 2004). This failure in source monitoring then constitutes the hallucinations that schizophrenics experience (Jeannerod and Pacherie, 2004). Regarding the OIs, future research could have implications for people that make memory errors at a pathological level, for example patients with Alzheimer's disease. The OIs can have dangerous consequences for the elderly, for example, if a person observes someone else taking a medication but then falsely remembers having taken the medication oneself (example taken from Lindner, 2010). Therefore of great interest for this research is to look at this paradigm in these patient groups. There is some research into mirror neurones and schizophrenia (e.g. Mohring et al., 2015; Andrews et al., 2015; Mehta et al., 2014)) and as far as I am aware, there is very little in Alzheimer's disease research. Using neuropsychology techniques in these patient cohorts will provide information about the brain areas and brain mechanisms involved in OIs and SAIs and will allow further investigation into mirror neurone involvement in OIs and SAIs.

12.3.4 Conclusions

Overall, the experiments of this thesis have demonstrated that observation of action alone can result in memories of self-performance (OIs), and that performing an action can be remembered as an action having been performed by another person (SAIs). This supports the finding of previous experiments on OIs (Lindner et al., 2010; Schain et al., 2012; Lindner and Davison, 2014). In addition to this, the experiments revealed that OIs and SAIs differed based on the type of action that is observed or performed. It was found that actions that are meaningful and communicative in nature are more likely to result in inflations. This result implies that mirror neurones could potentially stand behind OIs although much more research is needed as this is far from conclusive, especially given the result from the study of in-group and out-group action performance. This thesis has created a successful paradigm that can now be used in future study to further investigate source confusion errors using a variety of techniques.

References

Aizpurua, A., Garcia-Bajos, E. and Migueles, M. (2009) 'False memories for a robbery in young and older adults'. *Applied Cognitive Psychology,* 23:2, pp.174-187.

Allen, R.J. and Waterman, A.H. (2007) 'How does enactment affect the ability to follow instructions in working memory?'. *Memory and Cognition,* 43:3, pp. 555-561.

Amiri, M.S. and Daryabari, S.M. (2013) 'Determination of the effect of cognitive-behavioral therapeutic group and the study of self-imagination level in treatment of social anxiety disorder of the students'. *European Psychiatry*, 28:1, p.1.

Anderson, J.R. (1983) 'A spreading activation theory of memory'. Journal of Verbal Learning and Verbal Behavior, 22, pp.261-295.

Andrews, S.C., Enticott, P.G., Hoy, K.E., Thomson, R.H. and Fitzgerald, P.B. (2015) 'No evidence for mirror system dysfunction in schizophrenia from a multimodal TMS/EEG study'. *Psychiatry Research*, 228:3, pp.421-440.

Andric, M., Solodkin, A., Buccino, G., Golwin-Meadow, S., Rizzolati, G. and Small, S.L. (2013) 'Brain function overlaps when people observe emblems, speech and grasping'. *Neuropsychologia,* 51, pp.1619-1629.

Arnold, M.M. and Lindsay, D.S. (2007).' "I remember/know/guess that I knew-it-all-along!": Subjective experience versus objective measures of the knew-it-all-along effect'. *Memory & Cognition*, 35, pp.1854-1868.

Avanzini, P., Fabbri-Destro, M., Dalla Volta, R., Daprati, E. and Rizzolatti,G. (2012) 'The Dynamics of Sensorimotor Cortical Oscillations during the Observation of Hand Movements: An EEG Study'. *PLoS ONE*, 7:5 [online] Available at: doi:10.1371/journal.pone.0037534

Avenati, A., Sirigu, A. and Aglioti, S. M. (2010) 'Racial bias reduces empathic sensorimotor resonance with other-race pain'. *Current Biology*, 20:11, pp.1018-1022.

Baddeley, A.D., Hitch, G.J. and Allen., R.J. (2009) 'Working memory and binding in sentence recall'. *Journal of Memory and Language*, 61, pp.438-456.

Baddeley, A.D., Eysenck, M., and Anderson, M.C. (2014) *Memory (*2nd ed.).Hove: Psychology Press

Balota, D.A. (1983) 'Automatic Semantic Activation and Episodic Memory Encoding'. *Journal of Verbal Learning and Verbal Behavior*, 22, pp.88-104.

Bartlett, F.C. (**1932**) *Remembering: A* Study *in Experimental and Social Psychology*. Cambridge University Press.

Baym, C.L. and Gonsalves, B.D. (2010) ‘Comparison of neural activity that leads to true memories, false memories, and forgetting: An fMRI study of the misinformation effect’. *Cognitive Affective Behavioural Neuroscience,* 10:3, pp. 339-348.

Bergert, S. (2013) ‘How do our brain hemispheres cooperate to avoid false memories?’. *Cortex,* 49:2, pp.572-581.

Bodner, G.E. and Masson, M.E.J. (2003) ‘Beyond spreading activation: An influence of relatedness proportion on masked semantic priming’. *Psychonomic Bulletin and Review,* 10:3, pp.645-652.

Brass, M., Zysset, S. and von Cramon, Y. (2001) ‘The inhibition of imitative response tendencies’. *NeuroImage,* 14, pp.1416-1423.

Brass, M., Bekkering, H. and Prinz, W. (2001a) ‘Movement observation affects movement execution in a simple response task’. *Acta Psychologica,* 106, pp.3-22.

Brattan, V.C., Baker, D.H. and Tipper, S.P. (2014) ‘Visual and motor priming effects on prediction of observed action in the first and third person perspective’. *Journal of Vision,* 14:10, p.830.

Bruno, D.A. and Rutherford, A. (2010) ‘How many response options? A study of remember-know testing procedures’. *Acta Psychologica,* 134, pp.125-129.

Buccino, G., Vogt, S, Ritz, A, Fink, G.R., Zilles, K., Freund, H.J. and Rizzolatti, G. (2004) ‘Neural circuits underlying imitation learning of hand actions: an event-related fMRI study’. *Neuron,* 42:2, pp. 323-334.

Cabeza, R., Grady, C.L., Nyberg, L., McIntosh, A.R., Tulving, E., Kapur, S., Jennings, J.J. Houle, S. and Craik, F.I.M. (1997) ‘Age-Related Differences in Neural Activity during Memory Encoding and Retrieval: A Positron Emission Tomography Study’. *The Journal of Neuroscience,* 17:1, pp.391-400.

Caggiano, V., Fogassi, L., Rizzolatti, G.,Casile, A., Giese, M.A. and Their, P. (2012) ‘Mirror neurons encode the subjective value of an observed actions’. *Proceeding of the National Academy of Science,* 109:29, pp.11848-11853.

Calvo-Merino, B., Grezes, J., Glaser, D.E., Passingham, R.E. and Haggard, P. (2006) ‘Seeing or Doing? Influence of Visual and Motor Familiarity in Action Observation’. *Current Biology,* 16, pp.1905-1910.

Carmo, J.C. and Rumiati, R.I. (2009) ‘Imitation of transitive and intransitive actions in healthy elderly’. *Brain and Cognition,* 69:3, pp.460-464.

Casper, S., Zilles, K., Laird, A.R. and Eickhoff, S.B. (2010) ‘ALE meta-analysis of action observation and imitation in the human brain’. *NeuroImage,* 50, pp.1148-1167.

Chaminade, T., Meltzoff, A.N. and Decety, J. (2002) ‘Does the end justify the means? A PET exploration of the mechanisms involved in human imitation’. *NeuroImage,* 15, pp.318-328.

Cheng, Y., Lee, P.-L., Yang, C.-Y., Lin, C.-P., Hung, D. and Decety, J. (2008) ‘Gender differences in the mu rhythm of the human mirror-neuron system’. *PLoS ONE*, 3:5 [online] Available at: 10.1371/journal.pone.0002113.

Cheng, Y., Chou, K.H., Decety, J., Chen, I.Y., Hung, D., Tzeng, O.J. and Lin, C.P. (2009) ‘Sex differences in the neuroanatomy of human mirror-neuron system: a voxel based morphometric investigation’. *Neuroscience*, 158:2, pp.713-720.

Collins, A.M. and Loftus, E.F. (1975) ‘A spreading activation theory of semantic processing’. *Psychological Review*, 82, pp.407-428.

Conway, M.A., and Rubin, D.C. (1993) ‘The structure of autobiographical memory’. In Collins, A.E., Gathercole, S E., Conway, M A., and Morris, P.E. M. (Eds.), *Theories of memory* (pp. 103-137). Hove, Sussex, England: Erlbaum.

Conway, M.A. and Dewhurst, S.A. (1995) ‘The self and recollective experience’. *Applied Cognitive Psychology*, 9, pp.1-19.

Cook, J.L. (2012) 'Action observation and imitation in the healthy brain and in high-functioning adults with autism spectrum conditions.' Doctoral thesis, University College London.

Corradini, A. and Anonietti, A. (2013) 'Mirror neurons and their function in cognitively understood empathy'. *Consciousness and Cognition,* 22, pp.1152-1161.

Daprati, E., Francka, N., Georgrieffa, N., Proustc, J., Pacherie, E., Daleryd, J. and Jeannerod, M. (1997) 'Looking for the agent: an investigation into consciousness of action and self-consciousness in schizophrenic patients'. *Cognition,* 65, pp.71-86.

Davidson, P.S.R., Anaki, D., Ciaramelli, E., Cohn, M., Kim, A.S.N. and Murphy, K.J. (2008) 'Does lateral parietal cortex support episodic memory? Evidence from focal lesion patients'. *Neuropsychologia,* 46, pp.1743-1755.

Deese, J. (1959) 'On the prediction of occurrence of particular verbal intrusions in immediate recall'. *Journal of Experimental Psychology*, 58, pp.17-22.

Dennis, N.A., Daselaar, S. and Cabeza, R. (2007) 'Effects of aging on transient and sustained successful memory encoding activity'. *Neurobiology and Aging*, 28, pp.1749–1758.

Désy, M.-C. and Lepage, J.-F. (2013) ‘Skin color has no impact on motor resonance: Evidence from mu rhythm suppression and imitation’. *Neuroscience Research*, 77, pp.58-63.

Dewar, M., Cowan, N. and Della Sala, S. (2007) ‘Forgetting due to retroactive interference: A fusion of Muller and Pikzecker’s (1900) early insights into everyday forgetting and recent research on anterograde amnesia’. *Cortex*, 43:5, pp.616-634.

Dewar, M., Fernandez, G.Y., Cowan, N. and Della Sala, S. (2009) ‘Delaying interference enhances memory consolidation in amnesic patients’. *Neuropsychology*, 23, pp.627–634.

Donne, C.M., Enticott, P.G., Rinehart, N.J. and Fitzgerald, P.B. (2011) ‘A transcranial magnetic stimulation study of corticospinal excitability during the observation of meaningless, goal-directed, and social behaviour’. *Neuroscience Letters,* 498:1, pp.57-61.

Doyon, J., Bellec, P., Amsel, R., Penhune, V., Monchi, O., Carrier, J., Lehericy, S. and Benali, H. (2009) ‘Contributions of the basal ganglia and functionally related brain structures to motor learning’. *Behavioural Brain Research,* 199, pp.61-75.

Enticott, P.G., Kennedy, H.A., Bradshaw J.L., Rinehart, N.J. and Fitzgerald, P.B (2010) ‘Understanding mirror neurons: evidence from enhanced corticospinal excitability during the observation of transitive but not intransitive hand gestures’. *Neuropsychologia,* 48:9, pp.2675-2880.

Earls, H.A., Englander, Z.A. and Morris, J.P. (2013) ‘Perception of race-related features modulates neural activity associated with action observation and imitation’. *Neuroreport*, 24:8, pp.410-413.

Ferrari, P.F., Fogassi, L., Gallese, V. and Rizzolatti, G. (2003) ‘Mirror neurons responding to the observation of ingestive and communicative mouth actions in the monkey ventral premotor cortex’. *European Journal of Neuroscience*, 17:8, pp.1703-1714.

Ferrari, P.F., Rozzi, S. and Foggassi, L. (2005) ‘Mirror neurons responding to observation of actions made with tools in monkey ventral premotor cortex’. *Journal of Cognitive Neuroscience,* 17:2, pp.212-226.

Frith, C. (2005) ‘The self in action: Lessons from delusions of control’. *Consciousness and Cognition,* 14, 752–770.

Frithsen, A. and Miller M.B. (2014) ‘The posterior parietal cortex: comparing remember/know and source memory tests of recollection and familiarity’. *Neuropsychologia,* 61, pp.31-44.

Gallese, V., Fadiga, L., Fogassi, L. and Rizzolatti, G. (1996) ‘Action recognition in the premotor cortex’. *Brain*, 119, pp.593–609.

Gallo, D.A., Cotel, S.C., Moore, C.D. and Schacter, D.L. (2007) ‘Aging can spare recollection-based retrieval monitoring: The importance of event distinctiveness’. *Psychology and Aging*, 22, pp.209–213.

Gardiner, J.M., Kaminska, Z., Dixon, M., and Java, R.I. (1996) ‘Repetition of previously novel melodies sometimes increases both remember and know responses in recognition memory’. *Psychonomic Bulletin & Review*, 3, pp.366-371.

Gardiner, J.M., Ramponi, C. and Richardson-Klavehn, A. (2002) ‘Recognition memory and decision processes: A meta-analysis of remember, know, and guess responses’. *Memory,* 10, pp.83-98.

Garry, M., Manning, C.G. and Loftus, E.F. (1996) ‘Imagination Inflation: Imagining a Childhood Event Inflates Confidence that it occurred’. *Psychonomic Bulletin & Review,* 3:2, pp.208-214.

Garry, M. and Polaschek, D.L.L. (2000) ‘Imagination and memory’. *Current directions in Psychological Science,* 9, pp.6-10.

Geraci, L. and McGabe, D.P. (2006) ‘Examining the basis for illusory recollection: The role of Remember/Know Instructions’. *Psychonomic Bulletin and Review, 13,* pp.466-473.

Geraci, L., McCabe, D.P. and Guillory, J.J. (2009) ‘On interpreting the relationship between remember-know judgements and confidence: The role of instructions’. *Consciousness and Cognition,* 18, pp.701-709.

Gimbel, S.I. and Brewer, J.B. (2011) ‘Reaction time, memory strength, and fMRI activity during memory retrieval: Hippocampus and default network are differentially responsive during recollection and familiarity judgements'. *Cognitive Neuroscience,* 2:19, pp.19-23.

Gleissner, B., Meltzoff, A.N. and Bekkering, H. (2000) 'Children's coding of human action: cognitive factors influencing imitation in 3-year-olds'. *Developmental Science,* 3:4, pp. 405-414.

Gonsalves, B. and Paller, K.A. (2000) 'Neural events that underlie remembering something that never happened'. *Nature Neuroscience*, 3, pp.1316-1321.

Gutsell, J. N. and Inzlicht, M. (2010) 'Empathy constrained: Prejudice predicts reduced mental simulation of actions during observation of outgroups'. *Journal of Experimental Social Psychology*, 26, pp.841-845.

Haj, M., Fasotti, L. and Allain, P. (2012) 'Source monitoring in Alzheimer's disease'. *Brain and Cognition*, 80, pp.185-191.

Hadijkhani, N., Joseph, R.M., Snyder, J. and Tager-Flusberg, H. (2006) 'Anatomical differences in the mirror neuron system and social cognition network in autism'. *Cerebral Cortex,* 16:9, pp.1276-1282.

Hamajima, H., Masao, N., Fujiwara, N., Nakaaki, S. and Tatsumi, H. (2005) 'The difference in young and elderly adults on false memory: examination on the effect of retention interval'. *Shinrigaku Kenkyu,* 75:6, pp.511-516.

Hashtroudi, S., Marcia, J.K. and Chrosniak, L.D. (1990) 'Aging and qualitative characteristics of memories for perceived and imagines complex events'. *Psychology and Aging,* 5:1, pp.119-126.

Haslinger, B., Erhard, P., Attenmuller, E., Shroeder, U., Boecker, H. and Ceballos-Baumann, A.O. (2005) ‘Transmodal sensorimotor networks during Action Observation in Professional Pianists’. *Journal of Cognitive Neuroscience,* 17:2, pp. 282-293.

Heyes, C. (2010) ‘Where do mirror neurons come from?’. *Neuroscience and Behavioural Reviews,* 34, pp. 575-583.

Hobson, R.P. and Lee, A. (1999) ‘Imitation and identification in autism’. *Journal of Child Psychology and Psychiatry,* 40, pp.649-659.

Hofmann, S.G., Asnanni, A., Vonk, I.J.J., Sawyer, A.T. and Fang, A. (2012) ‘The Efficacy of Cognitive Behavioral Therapy: A Review of Meta-analyses’. *Cognitive Therapy and Research*, 36:5, pp.427-440.

Hommel, B., and Prinz, W. (1997) *Theoretical issues in stimulus response compatibility*. Amsterdam: North-Holland.

Horry, R., Wright, D.B. and Tredoux, C.G. (2010) ‘Recognition and context memory for faces from own and other ethnic groups: A remember-know investigation’. *Memory and Cogntion,* 38:2, pp. 134-141.

Horselenberg, R., Merckelbach, H., Muris, P., Rassin, E., Sijsenaar, M. and Spaan, V. (2000) ‘Imagining fictious childhood event: The role of individual differences in imagination inflation’. *Clinical Psychology and Psychotherapy,* 7:2, pp.128-137.

Horstein, S.L. and Mulligan N.W. (2004) ‘Memory for actions: self-performed tasks and the reenactment effect’. *Memory and Cognition,* 31:3, pp. 412-421.

Howard, D., Patterson, K., Wise, R., Brown, D., Friston, K., Weiller, C. and Frackowiak, R. (1992) ‘The cortical localizations of the lexicons: positron emission tomography evidence’. *Brain,* 115, pp.1769-1782.

Hunt, M. (2005) ‘Using source cues and familiarity cues to resist imagination inflation, *Acta Psychologica,* 120, pp.227-242.

Husain, F.T., Patkin, D.J., Kim, J., Braun, A.R. and Horwitz, B. (2012) ‘Dissociating Neural Correlates of Meaningful Emblems from Meaningless Gestures in Deaf Singers and Hearing Non-Singers’. *Brain Research,* 1478, pp.24-35.

Hyman, I.E. and Pentland, J. (1996). The role of mental imagery in the creation of false childhood memories, *Journal of Memory and Language,* 35, pp.101-117.

Iacoboni, M. (2009) ‘Imitation, Empathy, and Mirror Neurons’. *Annual Review of Psychology,* 60, pp.653-670.

Jacoby, L.L. (1999) ‘Deceiving the Elderly: Effects of accessibility bias in cued-recall performance’. *Cognitive Neuropsychology,* 16, pp.417-436.

Jacoby, L.L. and Rhodes, M.G. (2006) ‘False Remembering in the Aged’. *Current Directions in Psychological Science,* 15:2, pp.49-53.

Jacoby, L.L., Rogers, C.S., Bishara, A. and Shimizu, Y. (2012) 'Mistaking the recent past for the present: False seeing by older adults'. *Psychology and Aging,* 27*,* pp.22-32.

Java, R.I., Gregg, V.H. and Gardiner, J.M. (1997) 'What do people actually remember (and know) in 'Remember/Know' experiments?'. *European Journal of Cognitive Psychology,* 9, pp.187-197.

Jeannerod, M. and Pacherie, E. (2004) 'Agency, Simulation and Self-Identification'. *Mind and Language,* 19:2, pp.113-146.

Johnson, M.K., Hastroudi, S. and Lindsay, D.S. (1993) 'Source Monitoring'. *Psychological Bulletin,* 114:1, pp.3-28.

Karanian, J.M. and Slotnick, S.D. (2014) 'The cortical basis of true and false memory for motion'. *Neuropsychologia*, 54, pp.53-58.

Keerativittatayut, R., Kaewkamnerdpong, B., Laothamatas, J. and Sungkarat W. (2011) 'Mirror Neuron System Study on Eldely Using Dynamic Casual Modelling fMRI Analysis'. *World Academy of Science, Engineering and Technology,* 58, pp. 397-401.

Kilner, J.M, Paulignan, Y. and Blakemore, S.-J. (2003) 'An interference effect of observed biological movement on action'. *Current Biology,* 13:6, pp.522-525.

Koide, R., Ishii K., Kinjo, H., Tomidokoro, Y. and Tamaoka, A. (2010) 'Early detection of Alzheimer's disease using spatial source monitoring tasks'. *The Journal of the Alzheimer's Association,* 6:4, p. S365.

Krakauer, J.W. and Shadmehr, R. (2006) 'Consolidation of motor memory'. *Trends in Neuroscience,* 29, pp.58-64.

Landau, J.D., and Marsh, R.L. (1997) 'Monitoring source in an unconscious plagiarism paradigm'. *Psychonomic Bulletin and Review*, 4, pp.265-270.

Leavitt, F. (1997) 'False attribution of suggestibility to explain recovered memory of childhood abuse following extended amnesia'. *Child Abuse & Neglect*, 21, pp.265-272.

Leonard, G. and Tremblay, F. (2007) 'Corticomotor facilitation associated with observation, imagery and imitation of hand actions: A comparative study in young and old adults'. *Experimental Brain Research*, 177, pp.167–175.

Leynes, P.A. and Bink, M.L. (2002) 'Did I do that? An ERP study of memory for performed and planned actions'. *International Journal of Psychophysiology,* 45, pp.197-210.

Liepelt, R. and Brass, M. (2010) 'Top-down modulation of motor priming by belief about animacy'. *Experimental Psychology*, 57, pp.221–227.

Lindner, I., Echterhoff, G., Davidson, P.S.R. and Brand, M. (2010) 'Observation Inflation: Your actions become mine'. *Psychological Science,* 21, pp.1291-1299.

Lindner, I., Scain, C., Kopietz, R. and Echerhoff, G. (2012) 'When do we confuse self and other in action memory? Reduced false memories of self-performance after observing actions by an out-group versus in-group actor'. *Frontiers in Psychology,* 3, 467

Lindner, I. And Davidson, P.S.R. (2014) 'False memories in older adults action: Relationship with executive functions'. *Aging, Neuropsychology and Cognition,* 21, pp.560-576.

Lindsay, D.S. and Johnson, M.K. (1989) 'The eyewitness suggestibility effect and memory for source'. *Memory and Cognition,* 17:3, pp.349-358.

Loftus, E.F. and Palmer, J.C. (1974) 'Reconstruction of automobile destruction'. *Journal of Verbal Learning and Verbal Behavior*, 13, pp.585-589.

Loftus, E.F. (1975) 'Leading questions and the eyewitness report'. *Cognitive Psychology*, 7, pp.560-572.

Loftus, E.F, Miller, D.G. and Burns, H.J. (1978) 'Semantic Integration of Verbal Information into a Visual Memory'. *Journal of Experimental Psychology; Human Learning and Memory*, 4:1, pp.19-31.

Losin, E. A., Iacoboni, M., Martin, A., Cross, K.A. and Dapretto, M. (2012) 'Race modulates neural activity during imitation'. *Neuroimage*, 59:4, pp.3594-35603.

Ma, L., Wang, B., Narayana, S., Hazeltine, E., Chen, X., Robin, D.T., Fox, P.T. and Xiong, J. (2010) 'Changes in regional activity are accompanied with changes in inter-regional connectivity during four weeks motor learning'. *Brain research,* 8, pp.64-76.

Manzi, A. and Nigro, G. (2008) 'Long-term memory for performed and observed actions: retrieval awareness and source monitoring'. *Memory,* 16:6, pp.595-603.

Marsh, B.U., Pezdek, K. and Lam, S.T. (2014) 'Imagination perspective affects ratings of the likelihood of occurrence of autobiographical memories'. *Acta Psychologica,* 150, pp.114-119.

Mather, M., Henkel, L.A. and Johnson, M.K. (1997) 'Evaluating characteristics of false memory: remember/know judgments and memory characteristics questionnaire compared'. *Memory and Cognition,* 25:6, pp.826-837.

McGabe, D.P., Geraci, L., Boman, J.K., Sensenig, A.E. and Rhodes, M.G. (2011) 'On the validity of remember-know judgments: evidence from thin aloud protocols'. *Consciousness and Cognition,* 20:4, pp.1625-1633.

McMillan, T.M., Williams, W.H. and Bryant, R. (2003) 'Post-traumatic stress disorder and traumatic brain injury: a review of casual mechanisms, assessment, and treatment'. *Neuropsychological Rehabilitation,* 13, pp.149-164.

Mehta, U.M., Thirthalli, J., Aneelraj, D., Jadhav, P., Gangadhar, B.N. and Keshavan, M.S. (2014) ‘Mirror neuron dysfunction in schizophrenia and its functional implications: A systematic review’. *Schizophrenia Research*, 160:1-3, pp.9-19.

Meyer, D.E. and Schvaneveldt, R.W. (1971) ‘Facilitation in recognizing pair of words: Evidence of a dependants between retrieval operations’. *Journal of Experimental Psychology*, 90:2, pp.227-234.

Mickes, L., Seale-Carlisle, T. and Wixted, J.T. (2013) ‘Rethinking familiarity: Remember/Know judgements in free recall’. *Journal of Memory and Language,* 68, pp.333-349.

Mitchell, K.J., Johnson, M.K. and Mather, M. (2002) ‘Source Monitoring and Suggestibility to Misinformation: Adult Age-Related Differences’. *Applied Cognitive Psychology,* 17, pp.107-119.

Mohring, N., Shen, C., Hahn, E., Ta, T.M., Dettling, M. and Neuhaus, A.H. (2015) ‘Mirror neuron deficit in schizophrenia: Evidence from repetition suppression’. *Schizophrenia Research*, <Avialable Online> http://dx.doi.org/10.1016/j.schres.2015.07.035

Molengberghs, P., Cunnington, R. and Mattingley, J.B. (2009) ‘Is the mirror neuron system involved in imiation? A short review and meta-analysis’. *Neuroscience Biobehavioral Reviews,* 33, pp.975-980.

Montgomery, K.J., Isenberg, N., and Haxby, J.V. (2007) ‘Communicative hand gestures and object-directed hand movements activated the mirror neuron system’. *Social Cognitive Affective Neuroscience,* 2:2, pp.114-122.

Mukamel, R., Ekstrom, A.D., Kaplan, J., Iacoboni, M. and Fried, I. (2010) ‘Single Neuron Responses in Humans during Execution and Observation of Actions’. *Current Biology,* 20:8, pp.750-756.

Murata, F., Gallese, V., Luppino, G., Kaseda, M. and Sakata, H. (1997) ‘Object representation in the ventral premotor cortex (area F5) of the monkey’. *Journal of Neurophysiology,* 78, pp.2226-2230.

Nedelko, V., Hassa, T., Hamzei, F., Weiller, C., Binkofski, F., Schoenfeld, M.A., Tusher, O. and Dettmers, C. (2010) ‘Age-independent activation in areas of the mirror neuron system during action observation and action imagery. A fMRI study’. *Restorative Neurology and Neuroscience,* 28:6, pp.737-747.

Newman-Norlund, R.D., Ganesh, S., van Schie, H.T., De Bruijin, E.R. and Bekkering, H. (2009) ‘Self-identification and empathy modulate error-related brain activity during the observation of penalty shots between friend and foe’. *Social Cognitive Affective Neuroscience,* 4:1, pp.10-22.

Nigro, G. and Neisser, U. (1983) ‘Point of view in personal memories’. *Cognitive Psychology,* 15, pp.467-482.

Norman, K.A. and Schacter, D.L. (1997) ‘False recognition in younger and older adults: Exploring the characteristics of illusory memories’. *Memory and Cognition*, 25, pp.838-848.

Nudo, R.J. (2008) ‘Neurophysiology of motor skill learning’. *Learning and Memory: a Comprehensive Reference,* 3, pp.403-421.

Ocampo, B., and Kritkos, A. (2011) ‘Interpreting actions: The goal behind mirror neuron function’. *Brain Research Reviews*, 67:1-2, pp.260-267.

Okado, Y. and Stark, C.E.L. (2005) ‘Neural activity during encoding predicts false memories created by misinformation’. *Learning and Memory,* 12:1, pp.3-11.

Paulesu, E., Frith, C.D. and Frackowiak, R.S. (1993) ‘The neural correlates of the verbal component of working memory’. *Nature*, 362:6418, pp.342-345.

Perlovsky, L.I. and Ilin, R. (2013) ‘Mirror neurons, language, and embodied cognition’. *Neural Networks,* 41, pp.15-22.

Pezdek, K., and Roe, C. (1995) ‘The effect of memory trace strength on suggestibility’. *Journal of Experimental Child Psychology,* 60, pp.116-128.

Pezdek, K. (2001) ‘A cognitive analysis of the recovered memory/false memory debate’. *Journal of Aggression, Maltreatment and Trauma,* 4:2, pp.73-85.

Plancher, G., Guyard, A., Nicolas, S. and Piolino, P. (2009) ‘Mechanisms underlying the production of false memories for famous people’s names in aging and Alzheimer’s disease’. *Neuropsychologia,* 47:12, pp.2527-2536.

Porter, S.P., Bellhouse, S., McDougall, A. and Wilson, K. (2010) ‘A Prospective Investigation of the Vulnerability of Memory for Positive and Negative Emotional Scenes to the Misinformation Effect’. *Canadian Journal of Behavioural Science,* 42:1, pp.55-61.

Press, C., Bird, G., Flach, R. and Heyes, C. (2005) ‘Robotic movement elicits automatic imitation’. *Cognitive Brain Research,* 25, pp.632-640.

Press, C., Gillmeister, H. and Heyes, C. (2006) ‘Bottom-up, not top-down, modulation of imitation by human and robotic models’. *European Journal of Neuroscience,* 24, pp.2415-2419.

Press, C., Gillmeister, H. and Heyes, C. (2007) ‘Sensorimotor experience enhances automatic imitation of robotic action’. *Proceedings of the Royal Society,* 274, pp.2509-2514.

Pulvermuller, F., Moseley, R.L., Egorova, N. and Shebani, Z. (2014) ‘Motor cognition – motor semantics: Action-perception theory of cognitive and communicative cortical function’. *Neuropsychologia,* 55, pp.71-84.

Ries, M. and Marks, W. (2006) ‘Heightened false memory: a long-term sequela of severe closed head injury’. *Neuropsychologia,* 44:12, pp.2233-2240.

Rizzolatti, G., Fadiga, L., Gallese, V., Fogassi, L. (1996) ‘Premotor cortex and the recognition of motor actions’. *Cognitive Brain Research,* 3, pp.131-141.

Rizzolatti, G. and Arbib, M.A. (1998) ‘Language within our grasp’. *Trends in Neurosciences,* 21:5, pp.188-194.

Rizzolatti, G., Fogassi, L. and Gallesse, V. (2001) ‘Neurophysiological mechanisms underlying the understanding and imitation of action’. *Nature Reviews Neuroscience,* 2:9, pp. 661-670.

Robinson, J.A. and Swanson, K.L. (1993) ‘Field and observer modes of remembering’. *Memory,* 1:3, pp.169-184.

Roediger, H.L., III, and McDermott, K.B. (1995) ‘Creating false memories: Remembering words not presented in lists’. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, 21, pp.803-814.

Rugg, M.D. and Vilberg, K.L. (2012) ‘Brain networks underlying episodic memory retrieval’. *Current Opinion in Neurobiology*, 23:1, pp.1-6.

Ruiz-Gallego-Largo, T., Simon, T. and Suengas, A.G. (2012) ‘Age differences in Source Monitoring and Referent Discrimination’. *The Spanish Journal of Psychology*, 15:1, pp.20-28.

Rumiati, I.R. and Tessari, A. (2002) ‘Imitation of novel and well-known actions. The role of short-term memory’. *Experimental Brain Research,* 142, pp.425-433.

Rumiati, R.I., Weiss, P.H., Tessari, A., Assmus, A., Zilles, K., Herzog, H.R. and Fink, R.G. (2005) ‘Common and differential neural mechanisms supporting imitation of meaningful and meaningless actions’. *Journal of Cognitive Neuroscience*, 17:9, pp.1420-1431.

Schacter, D.,L. (1992) ‘Understanding implicit memory: A cognitive neuroscience approach’. *American Psychologist*, 47:4, pp.559-569.

Schacter, D.L., Alpert, N.M., Savage, C.R., Rauch, S.L., and Albert, M.S. (1996) ‘Conscious recollection and the human hippocampal formation: Evidence from positron emission tomography’. *Proceedings of the National Academy of Sciences*, 93, pp.321-325.

Schacter, D.L., Curran, T., Galluccio, L., Milberg, W., and Bates, J. (1996a) ‘False recognition and the right frontal lobe: A case study’. *Neuropsychologia*, 34, pp.793-808.

Schacter, D.L., Koutstaal., W. and Norman, K.A. (1997) ‘False memories and aging’. *Trends in Cognitive Science*, 1:6, pp.229-236.

Schain, C., Lindner, I., Beck, F. and Echterhoff, G. (2012) ‘Looking at the actor's face. Identity cues and attentional focus in false memories of action performance from observation’. J*ournal of Experimental and Social Psychology,* 48, pp. 1201-1204.

Schult, J., von Stulpnagel, R. and Stefens, M.C. (2014) 'Enactment versus Observation: Item-Specific and Relational Processing in Goal-Directed Action Sequences (and Lists of Single Actions)' *Plos one,* available at: < http://dx.doi.org/10.1371/journal.pone.0099985>

Senkfor, A.J., Van Petten, C. and Kutas, M. (2002) 'Episodic action memory for real objects: An ERP investigation with perform, watch, and imagine action encoding tasks versus a non-action encoding task'. *Journal of Cognitive Neuroscience*, 14:3, pp.402-419.

Senkfor, A.J., Van Petten, C. and Kutas, M. (2008) 'Enactment versus conceptual encoding: Equivalent item memory but different source memory'. *Cortex,* 44(6), pp. 649-664.

Skaggs E.B. (1933) 'A discussion on the temporal point of interpolation and degree of retroactive inhibition'. *The Journal of Comparative Psychology*, 16, pp.411–414.

Sharman, S.J. and Barnier, A.J. (2008) 'Imagining nice and nasty events in childhood or adulthood: Recent positive events show the most imagination inflation'. *Acta Psychologica,* 129, pp.228-233.

Sharman, S.J, Manning, C.G. and Garry, M. (2005) 'Explain this: explaining childhood events inflates confidence for those events'. *Applied Cognitive Psychology*, 19:1, pp.67-74.

Shimamura, A.P., Jurica, P.J. and Mangels, J.A. (1995) ‘Susceptibility to memory interference effects following frontal lobe damage: findings from tests of paired-associate learning’. *Journal of Cognitive Neuroscience*, 7, pp.144–152.

Sommerville, J.A. and Decety, J. (2006) ‘Weaving the fabric of social interaction: Articulating developmental psychology and cognitive neuroscience in the domain of motor cognition’. *Psychonomic Bulletin and Review,* 13:2, p.179-200.

Stefan, K., Cohen, L.G., Duque, J., Mazzocchio, R., Celnik, P., Sawaki, L., Ungerleider, L. and Classen, J. (2005) ‘Formation of motor memory by action observation’. *The Journal of Neuroscience,* 25:41, pp.9339-9346.

Sutin, A.R. and Robins, R.W. (2010) ‘Correlates and Phenomenology of 1st and 3rd Person Memories’. *Memory*, 18:6, pp.625-637.

Taube, W., Mouthon, M., Leukel, C., Hoogewoud, H.-M., Annoni, J.-M. And Keller, M. (2015) ‘Brain activity during observation and motor imagery of different balance tasks: An fMRI study’. *Cortex,* 64, pp.102-114.

Tessari, A., Bosanac, D. and Rumiati, R.I. (2006) ‘Effect of learning on imitation of new actions: implications for a memory model’. *Experimental Brain Research,* 173, pp.507-513.

Tessari, A., Canessa, N., Ukmar, M. and Rumiati, R.I. (2007) ‘Neuropsychological evidence for a strategic control of multiple routes in imitation’. *Brain,* 130, pp.1111-1126.

Tomasello, M., Call, J., Warrem, K.A., Frost, G.T., Carpenter, M. and Nagell, K.M. (1997) ‘The ontogeny chimpanzee gestural signals: A comparison across groups and generations’. *Evolution of Communication,* 1, pp.223-259.

Tomasello, M. (1999) *The cultural origins of human cognition.* Cambridge, MA: Harvard University Press.

Treur, J. and Umair. M. (2011) ‘A Cognitive Agent Model Using Inverse Mirroring for False Attribution of Own Actions to Other Agents’. *Modern Approaches in Cognitive Science,* 6704, pp.109-119.

Tulving, E. (1972) ‘Episodic and semantic memory’. In E. Tulving and W. Donaldson (Eds.), *Organization of memory* (pp.381-403). New York: Academic Press.

Tulving, E. (1985) ‘Memory and consciousness’. *Canadian Psychology,* 26, pp. 1-12.

Underwood, B.J. (1965) ‘False recognition produced by implicit verbal responses’. *Journal of Experimental Psychology,* 70:1, pp.122-129.

Underwood, J. and Pezdek, K. (1998) ‘Memory suggestibility as an example of the sleeper effect’. *Psychonomic Bulletin and Review,* 5:3, pp.449-453.

Wilson, M. and Knoblich, G. (2005) ‘The case for motor involvement in perceiving conspecifics’. *Psychological Bulletin,* 113, pp. 460-473.

Wriessnegger, S.C, Leeb, R., Kaiser, V., Neuper, C. and Muller-Putz, G.R. (2013) ‘Watching object related movements modulates mirror-like activity in parietal brain regions’. *Clinical Neurophysiology,* 124:8, pp.1596-1604.

Yamasue, H., Kuwabara, H., Kawakubo, Y. and Kasai, K. (2009) ‘Oxytocin, sexually dimorphic features of the social brain, and autism’. *Psychiatry and Clinical Neurosciences*, 63:2, pp.129-140.

Yonelinas, A.P., Otten, L.J., Shaw, K.N. and Rugg, M.D. (2005) ‘Separating the Brain Regions Involved in Recollection and Familiarity in Recognition Memory’. *The Journal of Neuroscience,* 25:11, pp.3002-3008.

Appendix 1: Source Memory Questionnaire (Experiment 1, Chapter 6)

INSTRUCTIONS

In Part 1 of the experiment you either observed or performed actions. Below is a short questionnaire designed to see how many actions you remember **performing yourself**.

Please answer **YES** if you recall performing any of these actions and **NO** if you do not recall performing these actions.

If your answer is **YES,** please decide the type of recollection you have for the particular action.

There are 3 potential responses:

(1) **Remember:** when you can retrieve qualitative details associated with performing the action. This can be any thoughts you had at the time or how you felt like when performing the action.

(2) **Know:** when you have a recollection of performing action, but you cannot retrieve any details about it. The action is familiar to you but you do not have any specific memories associated with it.

(3) **Guess**: when you answered 'yes', because you guessed that you performed the action.

Please answer these questions:	YES			NO
	Remember	**Know**	**Guess**	
1. I stuck a note to my nose.				
2. I turned on a lamp.				
3. I wrote down my address.				
4. I tapped my wrist with index finger as if I was trying to tell somebody to hurry up.				
5. I plugged in the lamp.				
6. I saluted.				
7. I screwed the light bulb into a lamp.				
8. I showed thumbs up.				
9. I stuck a note to a wall.				
10. I pointed to the door.				
11. I hid a sweet inside a book.				
12. I placed right hand on my chest as if I was swearing something to somebody.				
13. I moved my index finger as if I was threatening somebody.				
14. I pulled on my hair as if I was stressed.				
15. I pinched my nose with a toothpick.				

16. I pointed to forehead with my index finger as if I was trying to tell somebody they are stupid.				
17. I painted with lipstick on a light bulb.				
18. I smiled.				
19. I poured tea into a mug.				
20. I rolled a pen on a desk.				
21. I folded a corner of a document page.				
22. I wrote down my name.				
23. I moved my index finger across my throat as if I was threatening somebody.				
24. I highlighted a sentence in a document.				
25. I waved hands towards me to call somebody.				
26. I showed thumbs down.				
27. I wrote with pen in the air above my head.				
28. I placed USB stick on top of my head.				
29. I highlighted a sentence in a book.				
30. I rolled torch on a desk.				

31. I moved index finger in circles next to my ear as if I was trying to tell somebody they are stupid.				
32. I laughed.				
33. I wrote in the air above my head with a finger.				
34. I shook my head.				
35. I closed my nose with fingers as if I was telling somebody that something smells bad.				
36. I mixed the coffee with spoon.				
37. I stapled a document.				
38. I crossed my fingers as if I was wishing somebody good luck.				
39. I flashed a torch.				
40. I nodded with agreement.				
41. I folded a page in a book.				
42. I shrugged my shoulders.				
43. I poured juice into a cup.				
44. I snapped my fingers as if I was trying to remember something.				
45. I opened a can.				
46. I wrote down a date of my birth.				
47. I sharpened a pencil.				

48. I waved my hand as if I was greeting somebody.				
49. I opened a bottle.				
50. I put a coin to a piggybank.				
51. I combed my hair.				
52. I shook a bottle.				
53. I put batteries inside a torch.				
54. I broke a toothpick.				
55. I put sugar into a coffee.				
56. I folded a page in half.				
57. I lit a candle.				
58. I put a sweet inside a coffee.				
59. I smelled a flower.				
60. I touched my forehead with hand as if I was expressing disbelief or shock.				
61. I ate a sweet.				
62. I put staples inside a stapler.				
63. I attached a key ring to a pen.				
64. I watered a plant.				
65. I brushed my arm with a toothbrush.				
66. I moved my fingers as if I was trying to tell somebody they speak too much.				

67. I touched my forehead with a stapler.				
68. I placed a tissue on top of my head.				
69. I touched my ear with USB cable.				
70. I tore a page from a book.				
71. I pinched my thumb with a toothpick.				
72. I put an orange inside a mug and drunk from it.				
73. I put a pen inside a bottle.				
74. I placed a bulb on top of a bottle.				
75. I shook my fists in the air as if I was expressing victory or joy.				
76. I wrote with a finger on my arm.				
77. I made a circle with my index finger and thumb as if I was telling somebody 'okay'.				
78. I stirred the spoon in the air.				
79. I brushed a light bulb with a toothbrush.				
80. I drew on a coin with a pencil.				

Appendix 2: Source Memory Questionnaire (Experiment 2, Chapter 7)

INSTRUCTIONS

In Part 1 of the experiment you either observed or performed actions. Below is a short questionnaire designed to see how many actions you remember **observing**.

Please answer **YES** if you recall observing any of these actions and **NO** if you do not recall observing these actions.

If your answer is **YES,** please decide the type of recollection you have for the particular action.

There are 3 potential responses:

(4) **Remember:** when you can retrieve qualitative details associated with observing the action. This can be any thoughts you had at the time or how you felt like when observing the action.

(5) **Know:** when you have a recollection of observing action, but you cannot retrieve any details about it. The action is familiar to you but you do not have any specific memories associated with it.

(6) **Guess**: when you answered 'yes', because you guessed that you observed the action.

Please answer these questions. I recall observing a person:	YES			NO
	Remember	Know	Guess	
1. Sticking a note to their nose.				
2. Turning on a lamp.				
3. Writing down their address.				
4. Tapping their wrist with index finger as if they were trying to tell somebody to hurry up.				
5. Plugging in the lamp.				
6. Saluting.				
7. Screwing the light bulb into a lamp.				
8. Showing thumbs up.				
9. Sticking a note to a wall.				
10. Pointing to the door.				
11. Hiding a sweet inside a book.				
12. Placing right hand on their chest as if they were swearing something to somebody.				
13. Moving their index finger as if they were threatening somebody.				
14. Pulling on their hair as if they were stressed.				

15. Pinching their nose with a toothpick.				
16. Pointing to forehead with their index finger as if they were trying to tell somebody they are stupid.				
17. Painting with lipstick on a light bulb.				
18. Smiling.				
19. I poured tea into a mug.				
20. I rolled a pen on a desk.				
21. Folding a corner of a document page.				
22. Writing down their name.				
23. Moving their index finger across their throat as if they were threatening somebody.				
24. Highlighting a sentence in a document.				
24. Waving hands towards them to call somebody.				
25. Showing thumbs down.				
26. Writing with pen in the air above their head.				
27. Placing USB stick on top of their head.				
28. Highlighting a sentence in a				

book.				
29. Rolling torch on a desk.				
30. Moving index finger in circles next to their ear as if they were trying to tell somebody they are stupid.				
31. Laughing.				
32. Writing in the air above their head with a finger.				
33. Shaking their head.				
34. Closing their nose with fingers as if they were telling somebody that something smells bad.				
35. Mixing the coffee with spoon.				
36. Stapling a document.				
37. Crossing their fingers as if they were wishing somebody good luck.				
38. Flashing a torch.				
39. Nodding with agreement.				
41. Folding a page in a book.				
42. Shrugging their shoulders.				
43. Pouring juice into a cup.				
45. Opening a can.				
46. Writing down a date of their				

birth.				
47. Sharpening a pencil.				
48. Waving their hand as if they were greeting somebody.				
49. Opening a bottle.				
50. Putting a coin to a piggybank.				
51. Combing their hair.				
52. Shaking a bottle.				
53. Putting batteries inside a torch.				
54. Breaking a toothpick.				
55. Putting sugar into a coffee.				
56. Folding a page in half.				
57. Lighting a candle.				
58. Putting a sweet inside a coffee.				
59. Smelling a flower.				
60. Touching their forehead with hand as if they were expressing disbelief or shock.				

61. Eating a sweet.				
62. Putting staples inside a stapler.				
63. Attaching a key ring to a pen.				
64. Watering a plant.				
65. Brushing their arm with a toothbrush.				
66. Moving their fingers as if they were trying to tell somebody they speak too much.				
67. Touching their forehead with a stapler.				
68. Placing a tissue on top of their head.				
69. Touching their ear with USB cable.				
70. Tearing a page from a book.				
71. Pinching a thumb with a toothpick.				
72. Putting an orange inside a mug and drinking from it.				
73. Putting a pen inside a bottle.				
74. Placing a bulb on top of a bottle.				
75. Shaking their fists in the air as if they were expressing victory or joy.				
76. Writing with a finger on their				

arm.				
77. Making a circle with their index finger and thumb as if they were telling somebody ‘okay’.				
78. Stirring the spoon in the air.				
79. Brushing a light bulb with a toothbrush.				
80. Drawing on a coin with a pencil.				

Appendix 3: Source memory questionnaire in Experiment 4 (Chapter 9)

<u>INSTRUCTIONS</u>

In Part 1 of the experiment you either observed or performed actions. Below is a short questionnaire designed to see which actions you remember **<u>performing</u>** and **<u>observing</u>**.

Please answer '**observe'** if you recall observing an action and '**perform'** if you recall performing it.

Please decide the type of recollection you have for the particular observed or performed action.

There are 3 potential responses:

(7) **Remember:** when you can retrieve qualitative details associated with observing or performing the action. This can be any thoughts you had at the time or how you felt like when observing or performing the action.

(8) **Know:** when you have a recollection of observing or performing action, but you cannot retrieve any details about it. The action is familiar to you but you do not have any specific memories associated with it.

(9) **Guess**: when you answered 'yes', because you guessed that you observed or performed the action.

Please answer these questions. I recall :	Observing this action.			Performing this action.			I do not remember this action.
	Remember	Know	Guess	Remember	Know	Guess	
1. Sticking a note to a nose.							
2. Turning on a lamp.							
3. Writing down address.							
4. Tapping wrist with index finger to tell somebody to hurry up.							
5. Plugging in a lamp.							
6. Saluting.							
7. Screwing a light bulb into a lamp.							
8. Showing thumbs up.							
9. Sticking a note to a wall.							
10. Pointing to the door.							
11. Hiding a sweet inside a book.							
12. Placing right hand on chest to swear something to somebody.							
13. Moving index finger as if threatening somebody.							
14. Pulling on hair as if were stressed.							
15. Pinching nose with a toothpick.							
16. Pointing to forehead with index finger to try to tell somebody							

they are stupid.							
17. Painting with lipstick on a light bulb.							
18. Smiling.							
19. Pouring tea into a mug.							
20. Rolling a pen on a desk.							
21. Folding a corner of a document page.							
22. Writing down name.							
23. Moving index finger across throat as if threatening somebody.							
24. Highlighting a sentence in a document.							
25. Waving hands to call somebody.							
26. Showing thumbs down.							
27. Writing with pen in the air above head.							
28. Placing USB stick on top of head.							
29. Highlighting a sentence in a book.							
30. Rolling torch on a desk.							
31. Moving index finger in circles next to ear to tell somebody they are stupid.							
32. Laughing.							
33. Writing in the air above head with a finger.							
34. Shaking head.							
35. Closing nose with fingers to tell somebody that							

something smells bad.							
36. Mixing the coffee with spoon.							
37. Stapling a document.							
38. Crossing fingers to wish somebody good luck.							
39. Flashing a torch.							
40. Nodding with agreement.							
40. Folding a page in a book.							
41. Shrugging shoulders.							
42. Pouring juice into a cup.							
44. Snapping fingers as if trying to remember something.							
45. Opening a can.							
46. Writing down a date of birth.							
47. Sharpening a pencil.							
48. Waving hand to greet somebody.							
49. Opening a bottle.							
50. Putting a coin into a piggybank.							
51. Combing hair.							
52. Shaking a bottle.							
53. Putting batteries inside a torch.							
54. Breaking a toothpick.							
55. Putting sugar into a coffee.							
56. Folding a page in half.							
57. Lighting a candle.							
58. Putting a sweet inside a coffee.							
59. Smelling a flower.							

60. Touching forehead with hand to express disbelief or shock.							
61. Eating a sweet.							
62. Putting staples inside a stapler.							
63. Attaching a key ring to a pen.							
64. Watering a plant.							
65. Brushing arm with a toothbrush.							
66. Moving fingers to tell somebody they speak too much.							
67. Touching forehead with a stapler.							
68. Placing a tissue on top of head.							
69. Touching ear with USB cable.							
70. Tearing a page from a book.							
71. Pinching a thumb with a toothpick.							
72. Putting an orange inside a mug and drinking from it.							
73. Putting a pen inside a bottle.							
74. Placing a bulb on top of a bottle.							
75. Shaking fists in the air to express victory or joy.							
76. Writing with a finger on arm.							
77. Making a circle with index finger and thumb to tell somebody ‘okay’.							
78. Stirring the spoon in the air.							
79. Brushing a light bulb with a toothbrush.							

80. Drawing on a coin with a pencil.							

Appendix 4: Source memory questionnaire in Experiment 5 (Chapter 10)

ISTRUZIONI

Nella prima parte dell’esperimento ha osservato o eseguito delle azioni. Di seguito trova un breve questionario per vedere quante azioni ricorda di aver eseguito. La preghiamo di decidere il tipo di memoria che ha per l’azione specifica eseguita.

Risponda **SI** se ricorda di aver eseguito una di queste azioni e **NO** se non ricorda di aver eseguito queste azioni.

Se la risposta è **SI**, decida il tipo di ricordo che ha per quella specifica azione.

Ci sono 3 tipi di risposte possibili:

(1) **Ricordo**: quando è in grado di ricordare dettagli qualitative associati all’esecuzione dell’azione, come quello che ha pensato in quel momento o come si è sentito nell’eseguire l’azione.
(2) **So:** quando ha un ricordo di aver eseguito l’azione, ma non riesce a recuperare alcun dettaglio a riguardo. L’azione le risulta familiare ma non ha ricordi specifici associati a essa.
(3) **Credo:** quando ha risposto ‘sì’, perché ha supposto di aver osservato o eseguito l’azione.

Per favore risponda alle seguenti domande:	**SI**			**NO**
	Ricordo	**So**	**Credo**	
1. Mi sono baciato la punta delle dita e le ho aperte come per dire che qualcosa era meraviglioso.				
2. Mi sono spazzolato il braccio con uno spazzolino da denti.				
3. Ho eseguito dei movimenti sopra la mia testa come se stessi giocando a basket e lanciando la palla in un canestro.				
4. Ho messo una banana sul mio orecchio come se stessi parlando al telefono.				
5. Ho spostato le mani dal mio corpo come per dire a qualcuno ‘basta’.				
6. Ho messo un libro sulla mia testa.				
7. Mi sono chinato in Avanti.				
8. Ho eseguito movimenti circolari con un cucchiaio sul palmo della mia mano.				
9. Ho mosso la mano come per dire ‘ciao’ a qualcuno.				
10. Ho eseguito movimenti come se stessi tagliando un libro.				
11. Ho mosso le mani verso me stesso come se stessi dicendo a qualcuno di avvicinarsi.				
12. Mi sono messo un CD sulla spalla.				
13. Ho contato con le dita.				
14. Mi sono spazzolato i capelli con una forchetta.				
15. Ho strofinato la mia guancia con un ditto come per dire che qualcosa era delizioso.				
16. Ho eseguito dei movimenti come se stessi bevendo,				

tenendo una tazza vicino alla mia guancia.				
17. Ho mosso le mani lontano dal mio corpo come per dire a qualcuno che non sapevo qualcosa.				
18. Ho eseguito dei movimenti come se stessi guidando usando una bottiglia come volante.				
19. Ho messo l'indice e il police tesi vicino alla mia bocca come se stessi fingendo di bere.				
20. Mi sono toccata la fronte con una pinzatrice.				
21. Ho eseguito dei movimenti come se stessi pescando.				
22. Ho imitato l'atto del mangiare con una forchetta, muovendola verso il braccio anzi che verso la bocca.				
23. Ho battuto l'indice sul polso come se stessi dicendo a qualcuno che era in ritardo.				
24. Mi sono messo della cuffie sugli occhi.				
25. Ho mosso le mie mani su e giù come se stessi pregando.				
26. Mi sono disegnato sul dito con un evidenziatore.				
27. Alzare le spalle.				
28. Ho fatto un movimento con le dita sotto al mento come per dire a qualcuno che non mi importava.				
29. Ho mosso una garza di fianco al mio collo.				
30. Ho sventolato la mano all'altezza degli occhi come per dire a qualcuno ' non importa'.				
31. Ho toccata il mio orecchio con un cavo.				
32. Mi sono coperto gli occhi con la mano come per dire a qualcuno che non stavo guardando.				

33. Ho appiccicato un foglietto al mio naso.				
34. Ho toccata il mio police con l'indice come per dire 'OK'.				
35. Ho messo un'arancia in una tazza e ho finto di bere.				

36. Ho premuto il ditto indice sulle mie labra come per dire a qualcuno di fare silenzio.				
37. Ho eseguito dei movimenti come se stessi fumando una penna.				
38. Ho salutato.				
39. Ho picchiettato sul mio polso con un'arancia.				
40. Ho messo le mani sotto un lato della mia faccia come se stessi dicendo a qualcuno che avevo sonno.				
41. Mi sono pinzato il naso con una molletta.				
42. Mi sono tirato la pelle sotto l'occhio come se stessi dicendo a qualcuno di stare attento.				
43. Scuotere la testa.				
44. Ho eseguito dei movimenti come se stessi scattando delle foto con una penna.				
45. Fare movimenti come per stirare sul braccio.				
46. Ho messo la mano destra sul petto come se stessi giurando qualcosa a qualcuno.				
47. Ho spruzzato del deodorante in un bicchiere.				
48. Incrociare le dita per augura re buona fortuna.				
49. Ho messo la mano con il police il mignolo aperti vicino al mio orecchio come se stessi parlando al telefono.				
50. Ho scosso una bottiglia d'acqua vuota.				
51. Ho mosso il ditto indice e il ditto medio come se stessi imitando una camminata.				
52. Mi sono pizzicato il naso con uno stuzzicadenti.				
53. Ho messo due dita davanti ai miei occhi e le ho spostate in Avanti come se stessi dicendo a qualcuno che lo stavo guardando.				
54. Ho fatto rotolare una penna sulla mia testa.				
55. Ho unito le mie dita e ho mosso la mano su e giu come se stessi chiedendo a qualcuno cosa volesse.				
56. Ho messo assieme le mie dita e ho disegnato una linea nell'aria come per dire che qualcosa era				

perfetto.				
57. Schioccare le dita come se si tentasse di ricordare qualcosa.				
58. Ho eseguito movimenti come se fumassi, muovendo una sigaretta verso le mie sopracciglia.				
59. Spazzolare una lampadina con uno spazzolino da denti				
60. Ho strofinato le mie dita tra loro come per dire 'soldi'.				
61. Muovere l'indice in cerchio vicino all'orecchio per dire a qualcuno che e` stupido.				
62. Ho fatto un ventaglio con delle carte e le ho messe dietro la mia testa.				
63. Ho mosso il mio indice e il pollice da un lato all'altro come per dire al qualcuno ' niente'.				
64. Ho scritto con una penna su un CD.				
65. Ho imitato l'atto dello sparare. 66. Far rotolare un accendino sulla faccia.				
67. Ho eseguito dei movimenti come se pettinassi, dalla fronte al mente.				
68. Ho strofinato le mie mani tra loro, come per comunicare anticipazione.				
69. Muovere i pugni in aria come per esprimere vittoria o gioia.				
70. Mi sono messo un fazzoletto sulla testa.				
71. Mi sono messo le dita in bocca per esprimere disgusto.				
72. Ho mosso le dita come se stessi tagliando con le forbici.				
73. Ho attaccato un portachiavi al mio orecchio. 74. Sfregare un fiammifero sul braccio.				
75. Ho fatto dei movimenti come se stessi mangiando con la mano.				
76. Ho messo una lampadina sul collo di una bottiglia.				

77. Ho messo la mano accanto all'orecchio come se stessi cercando di ascoltare.				
78. Mi sono coperto l'occhio con un cucchiaio.				
79. Muovere un block notes sul braccio.				
80. Ho mosso le braccia come se stessi guidando.				
81. Ho attaccato un portachiavi a una penna.				
82. Ho mosso le dita su e giù come per dire a qualcuno che parlava troppo.				
83. Mettere una caramella nel caffe`.				
84. Ho eseguito dei movimenti come se stessi giocando a tennis con una tazza.				
85. Mi sono coperto le orecchio come per dire a qualcuno che non lo stavo ascoltando.				
86. Pollici verso il basso				
87. Mi sono pizzicato il pollice con uno stuzzicadenti.				
88. Ho picchiettato sulla mia fronte con l'indice come per dire a qualcuno che era pazzo.				
89. Ho scritto nell'aria con il dito.				
90. Ho messo la mano sulla fronte e l'ho mossa come a esprimere sollievo.				

91. Ho incrociato gli indici all'altezza della bocca e li ho baciati da entrambi i lati, come per giurare.				
92. Ho bucato una busta con una penna.				
93. Ho girato il palmo su e giù come per dire 'più o meno'.				
94. Ho messo delle graffette in un salvadanaio.				
95. Ho disegnato con un evidenziatore su un piatto.				
96. Ho mosso velocemente la mano all'altezza degli occhio come se stessi minacciando qualcuno di picchiarlo.				
97. Ho incrociato i miei polsi come per dire che qualcuno è stato arrestato.				
98. Pollici su.				
99. Ho picchiettatto sulla mia fronte con il palmo verso il basso come per dire che qualcuno è pazzo.				
100. Ho eseguito dei movimenti come se tagliassi il mio polso.				
101. Ho applaudito.				
102. Mi sono scritto sul braccio con il dito. 103. Tirarsi I capelli come se si fosse stressati.				
104. Ho mosso il mio dito indice come se stessi minacciando qualcuno.				
105. Ho scritto su una moneta con una penna.				
106. Ho mosso la mano con il palmo aperto davanti a me come per dire a qualcuno di fermarsi.				
107. Mi sono messo una chiavetta usb sulla testa.				
108. Ho nascosto una caramella in un libro.				
109. Dipingere con il rossetto su una lampadina.				

110. Ho fatto passare una torcia sul mio braccio.				
111. Ho spazzolato una lampadina con uno spazzolino da denti.				
112. Ho messo una penna in una bottiglia.				
113. Mi sono strofinato la guancia con una gomma per cancellare.				
114. Ho scritto nell'aria con una penna.				
115. Ho eseguito movimenti come se mi stessi radendo sul petto-				
116. Attaccare un biglietto al muro.				
117. Ho illuminato una bottiglia con una torcia-				
118. Ho eseguito dei movimenti come se cercassi di aprire qualcosa, con la chiave rivolta verso l'alto.				
119. Mi sono messo un dito sul labbro e ho guardato in alto, come se stessi pensando a qualcosa.				
120. Ho ripetutamente aperto e chiuso il mio palmo rivolto verso l'alto come per dire a qualcuno che avevo paura.				
121. Indicare la porta.				
122. Mi sono toccato le orecchie con le dita e mi sono mosso seguendo un ritmo come se stessi ascoltando della musica.				
123. Ho steso il braccio e alzato l'indice come per dire a qualcuno di aspettare.				
124. Far rotolare una penna sulla scrivania.				
125. Ho eseguito dei movimenti come se stessi distribuendo qualcosa a qualcuno.				
126. Mi sono dato un pugno in testa come per dire a qualcuno che era testardo.				
127. Rompere uno stuzzicadenti.				
128. Ho eseguito dei movimenti, come se stessi giocando a tennis.				